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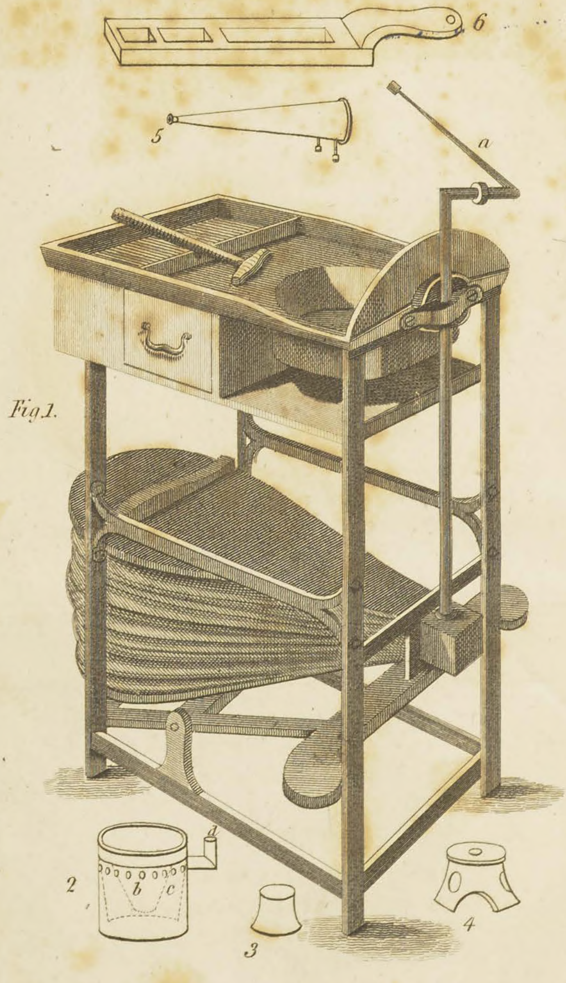

J. K. Paulding 1/25

A MANUAL
OF
ANALYTICAL MINERALOGY,

INTENDED TO FACILITATE THE

PRACTICAL ANALYSIS OF MINERALS.

IN TWO VOLUMES.

BY

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EARTHY MINERALS,

OR

EARTHS AND STONES.

VOL II.

THE orders of stones, like those of the ores of metals, are founded on the fundamental property of their constituent parts. Each order derives its name from the particular earth which constitutes its most predominant part, and to this the different earths and stones, in which the simple earth forms the predominant, or at least the most characteristic one, are referred, allowance being made for the present imperfections of

chemical analysis, and due attention being paid to analogies of other properties.

The number of simple earths known at present amount to nine. They are the following:

Silex, or Flint,	Barytes
Lime, or Calcareous Earth,	Strontia,
	Glucine,
Alumine, or Clay,	Zircon,
Magnesia,	Yttria.

It is obvious, therefore, that the same orders of stones must exist.

In the strictest sense of the word, there is certainly no natural foundation for such divisions, because the discoveries of chemists have shewn that several stones are composed of two, three, or even four simple earths, and in other instances the earths of which the stone is composed are present in nearly equal quantities; hence with some mineralogists it has not been so much the chemical composition as the external characters which have been adopted in the distribution of these mineral substances.

Whenever the analysis of a stone, or earthy compound has been effected, we have reason to presume that a similarity of composition will exist

in other specimens which agree with it closely in external properties or characters.

CHARACTERISTIC PROPERTIES OF EARTHS AND STONES.

Stones, if considered chemically, are either masses of simple earth or different earths, chemically combined, or earths united to an acid; they sometimes contain a small quantity of an alcali, but more generally some metallic oxids; the latter give to them the beautiful colours which many of them exhibit.

The class of earth and stones are sufficiently distinguished from other minerals by certain negative properties. They may be discriminated from ores by their specific gravity being always below 5, and by their acid solutions not being precipitable by prussiates, nor by water impregnated with sulphuretted hydrogen (yttria excepted) they are distinguished from inflammable fossils by their incapability of burning in contact with air, or when heated with nitrates, or with hyperoxe muriate of potash, and from the class of salts, by their want of saline taste, and insolubility in water.

NATURAL HISTORY OF EARTHS AND STONES.

The slightest acquaintance with the stony substances that come under our inspection, is sufficient to convince us that they were once in a soft or liquid state. A vast number of them have a regular symmetrical arrangement, they have been crystallized like salts, and must therefore have been separated from their solvent, whatever that may have been. The variety of crystals of stones discover all the figures and modifications of forms, observable in other substances, when suffered to crystallize under favourable circumstances. Moreover, many stones inclose organized substances, which they could not have admitted, but when in a soft or fluid state; others are evidently formed round different bodies, as these, having received their shape and form, the operations of art could never have introduced themselves into them.

The mere inspection of the general masses of our earth, the totality of which have a tabular form, called mineral strata, also convinces us that the surface of our globe has at one time been in a fluid state, to the greatest depth as well as the utmost height which have yet been reached.

The parallelism of the mineral strata can be accounted for on no other rational principle, it could have been produced only by subsidence from a fluid at rest, and as it extends over the entire surface of the earth, it establishes the general fluidity of the whole. The spheroidal figure of our globe itself is a demonstration that its surface to a depth much greater than we have penetrated must have been at one time fluid, or at least soft and yielding.

The bare mention of these circumstances is sufficient, as this point cannot possibly be disputed. The only difficulty that offers itself is, to ascertain the nature of that fluid which was capable of holding in solution, or perhaps in suspension, that immense mass of solid substances of which the stony part of the globe consists. Concerning this subject different theories have been advanced. Kirwan remarks, that with regard to stony matters placed deeper than one mile beneath the level of the sea, we have no reason to affirm that they were ever in a soft state, as we are absolutely unacquainted with them; with respect to those that are nearer to, or on the surface of the earth, we may for the present suppose that fluid to have been in most cases

mere water, in some circumstances assisted by other agencies, and in comparatively much fewer cases, aided by volcanic fires. In vain, however, have philosophers endeavoured to form perfect theories of this subject. If it were permitted to man to follow, during several ages, the various changes which are produced on the surface of our globe, by the numerous agents that alter it, we might perhaps be in possession at this moment of the most valuable information respecting this subject; but thrown as we are upon a small point of this vast theatre of observation, we can only fix our attention for a minute to reason upon subjects which have employed the works of nature for ages, and disappear ourselves at the moment wherein we have proceeded so far as to collect a few facts.

It must nevertheless be acknowledged that those men who by the mere efforts of their imagination, have endeavoured to form ideas respecting the construction and the great phenomena of this subject, have numerous claims to our indulgence. Amongst these we have to mention particularly Kirwan, Hutton, and Werner. In their proceedings we behold the efforts of genius tormented with the desire of acquiring knowledge, and irritated at the prospect of the

scanty means which nature has put in its power. They have endeavoured to embellish their hypotheses with every ornament which imagination and eloquence can furnish, either as instruments of illusion or entertainment: we ought to consider ourselves highly indebted to them.

For a circumstantial detail of these theories, as well as the nature and position of the mineral strata, their geometrical measurement, and modes of exploring them, &c. the reader is referred to the author's System of Mineralogy and Mineralogical Chemistry, vol I. part II. sect. 1 to 5, and part III. sect. 1, 2, and 3.

ANALYSIS OF EARTHS AND STONES.

The class of minerals called earths and stones, being far more extended than those called ores, which we have considered, no general method of analysis can be given that might prove useful to the student of mineralogical chemistry. We shall therefore adhere to the mode already adopted and shall examine the different orders of earths and stones, one by one.

ORDER I.

SILICEOUS STONES.

Division of Siliceous Stones.

The stones in which flint abounds are very abundantly diffused throughout the world.—They appear to have been intended by nature to constitute the nucleus or solid part of our globe, to serve as a foundation for the original mountains, and to give them that hardness and durability which has enabled them to resist the various revolutions which the surface of our planet has successively undergone. The profoundest excavations that have hitherto been made by art into the crust of our earth, have all uncovered a rock called granit which is chiefly composed of flint.

The stones belonging to this order, are more numerous than the rest.

The greatest number of the most beautiful stones, which are cut and polished, and worn as luxuries or ornament, belong to this class, such as the Bohemian ruby, the occidental topaz, the

amethyst, and all the gems distinguished by lapidaries and jewellers, by the term occidental, besides those beautiful stones known by the names of carnelian, agate, opal, mocha stones, jaspar, calcedony, &c.

The order of siliceous stones may be considered under the following heads: namely,

GENUS I.

Siliceous Stones almost wholly composed of flint, or siliceous earth in a state nearly pure.

GENUS II.

Siliceous Stones composed chiefly of flint, with a portion of alumine.

GENUS III.

Siliceous Stones composed chiefly of silex, and a portion of alumine and lime.

GENUS IV.

Siliceous Stones composed chiefly of silex united to magnesia and lime.

GENUS V.

Siliceous Stones composed chiefly of silex, combined with magnesia, lime, and alumine.

Genus VI.

Siliceous Stones composed chiefly of silex, combined with alumine and barytes.

Genus VII.

Siliceous Stones composed chiefly of silex, united to alumine or lime, or both, and a portion of an alcali.

The metallic oxids which are usually met with in all stones, we omit to notice in the arrangement.

CHARACTERS OF SILICEOUS STONES.

Most, or at least, a great number of the stones belonging to this order are transparent; they have a vitreous appearance, and a high polish, at least when almost wholly composed of silex. They are very hard, when pulverised they form a powder harsh to the touch, which scratches or wears away metals, and scratches glass. They are not acted upon by any acid, the fluoric excepted. They likewise fuse with alcalies, and form with them, in certain proportions, glass. They also

melt with glacial acid of phosphorus, and with boracic acid. They do not adhere to the tongue, they do not discover any peculiar odour when breathed on, nor do they form a tenacious mass with water. Their specific gravity is seldom more than 2,88.

It is obvious that every one of these characters is not rigorously applicable to each of these bodies. But the totallity of them possess a certain number, which renders these preliminary statements, perhaps useful to beginners.

When a stone possesses some, or most of the characters which may be considered as peculiar to the siliceous order, we may proceed to ascertain with more certainty whether it really belongs to it, or not, in the following manner:

ANALYSIS OF SILICEOUS STONES.

Genus I.—*Analysis of Siliceous Stones almost wholly composed of Flint or Silex, in a state nearly pure.*

Process I.—Let a weighed quantity of the stone, broken into small fragments, be heated to redness in a covered crucible, plunge it suddenly into cold water, and repeat this operation for

several times successively, or till the stone is become considerably friable. Another portion of the stone may be heated red-hot for some hours and weighed, to learn whether it sustained any loss during this operation, which loss, if any, is water.

II.—Having done this reduce one part of the stone, thus previously rendered pulverisible, to an impalpable powder, in an agate mortar, mix it with four parts of potash, dissolved in a like quantity of water, put the mixture into a silver crucible or bason, and evaporate it over the flame of a lamp, or in a sand-bath to dryness, keeping it constantly stirred with a silver rod, to prevent the mixture from swelling and throwing part of the mass out of the crucible or bason. When the whole is evaporated to perfect dryness, place the silver crucible into a larger earthen-ware one, surrounded by sand, and expose it to a dull red heat just sufficient to fuse the mass, and keep it in that state for at least two hours, taking care not to augment the fire which would endanger the melting of the silver crucible. Instead of potash, as here directed, carbonate of potash may be used, but in that case at least six parts of the salt to one of the stone should be employed, the former however is preferable.

From the appearance of the fused alcaline mass in the crucible, some conjectures may be formed respecting the predominant earth contained in the stone; for if the mass flows thin like oil, we may be certain that silex forms the most predominant part. If it fuses pasty, opake, and is apt to swell and puff up, we are certain that silex does not form the chief constituent part, but that other earths are present in considerable quantity. If the mass when cold is of a reddish or brown colour, it contains probably a portion of oxid of iron, and if green, oxid of manganese may be suspected.

III.—When the mass has been fused, as stated before, remove the crucible out of the fire, wipe it quite clean on its outside, place it in a bason, and soften the contents of it, by dropping into it distilled water, and lastly effect a solution by adding to it about 10 or 12 times its weight of water, and boil the mixture for a few minutes in a Florence flask, or bason. If the stone was composed entirely of silex, a compleat solution will be the result. If it contained other earths, or oxids of metals, they will remain behind undissolved. These may be separated by fil-

tration, and the modes of examining them will be seen in the sequel.

IV.—To the obtained alcaline solution add gradually muriatic acid. The first portion of the acid which is added will occasion a flocculent precipitate, which will increase by adding more acid, and give the whole a gelatinous appearance; but, if no precipitate should ensue, the acid should be added in excess.

V.—The obtained gelatinous mass, or apparent solution, should next be evaporated to dryness in a glass or wedgwood bason; if the fluid was transparent it will certainly assume a gelatinous form as it becomes more concentrated by evaporation; it should then be diligently stirred with a glass rod, till it has a granular appearance like sand, taking care not to heat it too much.

VI.—Transfer this mass into a Florence flask, cover it with muriatic acid, and digest it in that fluid for some time, decant the fluid, wash the residue, and add the water employed for that purpose to the decanted acid. The solid product obtained is silex. If it be pure it will be perfectly white, entirely insoluble in sulphuric, nitric, and muriatic acid. If it be coloured, it is contaminated with some metallic oxid, and

shows that the evaporation to dryness has been performed with too much heat.

From the metallic oxid it may be freed by digestion in muriatic acid, or by igniting the whole with a little wax, and then digesting it in muriatic acid, which operation will render the oxid soluble in the acid, from which it may be separated by adding to it ammonia in excess. The silex thus purified is perfectly white, and insoluble in sulphuric, nitric, and muriatic acid: let it be freed from its water by exposing it to a red heat, and then weigh it. The deficiency of the weight of the sum total, gives the quantity of foreign bodies that are contained in the muriatic solution, process VI. or which are not acted on by the alcali in process I. The mode of separating them will be exhibited presently. The quantity of oxid of iron which is usually present in all coloured stones, may be separated by prussiate of potash, or succinate and ammonia.

To render what has been stated as obvious as possible, we shall advance several analyses of siliceous stones, as performed by Klaproth.*

* Analytical Essays, vol. I. p. 440.

Example 1.—*Analysis of the Noble Opal.*

Process I.—A piece of noble opal, weighing 76½ grains, was exposed to heat, in a covered crucible. It crackled at the very first application of the fire. When the noise had ceased, it was kept in ignition for half an hour longer. After cooling, the stone was found broken into small slaty splinters, of a milk-white colour and of an enamelled lustre. The yellowish ochry covering, which is perceivable even in the rough stone, and which often penetrates its minute fissures, was changed to a high yellow-red, exhibiting the colours of the rainbow. Its loss in weight was 7½ grains, or about 10 per cent. which is to be considered as water.

II.—Hundred grains of the same stone were next finely pulverized in a flint mortar with water, and mixed with 300 grains of soda, the mixture was subjected to a moderate red-heat for two hours, in a silver crucible.

III.—The alcaline mass, obtained in process II. was gradually softened with water, supersaturated with muriatic acid, and then digested in that fluid. The fluid formed a gelatinous mass as it cooled. This mass being again

diluted with water, and again digested in muriatic acid, yielded silex in the form of a white powder, which being thoroughly washed and ignited, weighed 90 grains.

IV.—The muriatic solution, together with the water employed for washing the silex, was reduced to a small bulk by evaporation, and mingled with liquid ammonia in excess; by this means only a very small quantity of a brownish flocculent precipitate separated, consisting of oxid of iron, amounting to about $\frac{1}{10}$ of a grain, after being ignited.

But, since the very pure white colour of the ignited opal evidently proved, that this slight portion of oxid of iron does not essentially belong to its constitution; and since, besides, not the least perceptible trace of any other earth appeared, Mr. Klaproth only reckons the real constituent parts of the noble opal, the following:

Silex	90
Water	10
	100

Example 2.—*Analysis of the White Opal.*

Process I.—Half an ounce of this stone, finely levigated, and intimately blended with one ounce of soda, was moderately ignited for two hours. The obtained mass was ground to powder, saturated with muriatic acid in excess; then evaporated nearly to dryness, again diluted with water, and finally thrown upon the filter. The residue being washed, dried, and ignited, yielded 237 grains of silex.

II.—The fluid from which the silex had been separated was diminished by evaporation, and combined with liquid ammonia; it afforded a slight quantity of a brownish precipitate. As the remaining fluid continued unaltered, on being mingled with carbonate of soda, it shewed, by this, that it held no other substance in solution, for otherwise a precipitate would have ensued.

III.—The precipitate obtained in process II. being re-dissolved in muriatic acid, and decomposed by dropping into it prussiate of potash, afforded some Prussian blue, of which the oxid of iron, that enter as a constituent part into this opal, was estimated, at most, one quarter of a grain. This being separated, carbonate of soda, added

to the solution, still precipitated half a grain of alumine earth, which, after ignition, could not be estimated at more than one-quarter of a grain.

Thus it was found that the stone called white or common oxpal, consists chiefly of silex; for half an ounce of it yielded:

Silex............	237	grains.
Alumine	0,25	
Oxid of iron	0,25	
	237,50	
Loss	2,50	
	240 grs. or $\frac{1}{2}$ oz.	

Example 3.—*Analysis of the Yellow, or Pitch Opal.*

Process I.—One hundred grains of this fossil, broken into coarse fragments, were exposed to red-heat for half an hour in a covered crucible. The stone flew in pieces, with a crackling noise. It was slightly transparent, after this ignition, but only on the edges; its colour also was changed into a pale brownish-yellow, and the loss

of weight, which it experienced, amounted to five grains. After this operation it was found very friable, and allowed of being easily ground to a subtle yellow powder.

Remark.—A stronger heat renders this opal greyish-white. The slight portion of iron which it contains, and from which it derived its colour, is reduced, in this process, to the reguline state; for by means of a good magnifying lens, extremely fine grains of iron, that have transuded, may then be discovered.

II.—The above-mentioned 95 grains of ignited and pulverised opal were mixed with 200 grains of dry carbonate of soda, or such as had lost its water of crystallization on exposure to the air, and the mixture exposed to a moderate red heat during one hour. It was next softened with water; supersaturated with muriatic acid; concentrated by evaporation to a hard jelly; once more diluted with water; and, lastly, thrown upon the filter. The silex, which, by this management was obtained, weighed 93½ grains, after having been ignited.

III.—The colourless muriatic fluid from which the silex had been obtained, was then mingled with liquid ammonia, added in excess. By this means a few brown flocks separated, which

collected and ignited, afforded one grain of oxid of iron. The remainder of the fluid contained no other ingredient.

Hence one hundred grains of the yellow opal, consist of:

Silex	93,5
Oxid of Iron	1
Water	5
	99,5

Example 4.—*Analysis of the Brown-Red Semi-Opal.*

Process I.—One hundred grains of this stone finely levigated, were mixed with a solution of potash, containing 300 grains of solid alcali. The mixture, being first evaporated to dryness in a silver vessel, was next ignited for half an hour. On being suffered to cool it was softened with water; super-saturated with muriatic acid; next inspissated to a gelatinous consistence, and again diluted with water, digested, and filtered. The siliceous earth thus obtained, after being ignited, weighed 43½ grains.

II.—The muriatic solution was combined with liquid ammonia in excess. A quantity of brown oxid of iron fell down, which weighed 47 grains, when washed, dried, and ignited. The fluid left by this, remained unchanged, when combined with carbonate of potash: hence it contained no other earths or metallic oxids.

III.—The oxid of iron was re-dissolved, in muriatic acid, and precipitated by prussiate of potash. After the separation of this blue prussiate of iron, the remaining solution was examined, first with liquid ammonia, and next with carbonate of soda. It suffered no change in either case.

Therefore this stone, which, from its large proportion of iron, might, perhaps, deserve to be classed under the genus of iron ores, with the denomination of opaline iron stone, is, in the hundred, composed of

Silex	43,50
Oxid of iron	47
Water	7,50
	98

Such is the mode of examining stones chiefly composed of silex, we shall now proceed to the examination of those in which alumine enters as a constituent part.

GENUS II.—*Analysis of Siliceous Stones chiefly composed of Silex and Alumine.*

Process I.—Take one part of the finely levigated stone, fuse it with potash, as directed before, process II. page 324; soften the mass with water, as stated, process III. decompose the alcaline solution by muriatic acid, and ascertain the quantity of silex, according to the rules of process IV. V. VI. &c.

II.—Having learnt the quantity of silex, endeavour to effect a solution of the mass which resisted the action of the alcali, in process II. and which consequently could not be dissolved in water, nor perhaps by the muriatic acid; digesting it in that fluid, and then mingle, this solution with the muriatic fluid from which the silex has been obtained. Concentrate the whole by evaporation as much as possible, and add to it, while boiling hot, a solution of carbonate of potash or soda, till no more precipitate ensues. Separate the precipitate by the filter, wash, and dry it. The precipitate obtained con sists of alumine, if no other earths were present in the stone.

III.—To separate and to ascertain the quan-

tity of this earth, transfer the precipitate into a Florence flask; pour over it about 3 times its weight of a concentrated solution of potash or soda, evaporate the mixture nearly to dryness, add to it water, and separate the insoluble part, if any, by the filter. The alumine will thus be dissolved in the potash or soda, whilst the other substances remain untouched in the form of a powder.

IV.—To ascertain the quantity of alumine, decompose the alcaline solution by the admixture of muriatic or nitric acid, taking care to add the acid in excess, so that the precipitate which first appeared becomes re-dissolved.

V.—Into the muriatic solution drop carbonate of ammonia in excess. The precipitate thus produced is carbonate of alumine. This precipitate after having been washed, dried, and exposed to a low red-heat in a crucible, gives the quantity of pure alumine, which was present in the stone, with tolerable accuracy.

Alumine may likewise be separated by ammonia, but not compleatly. For that purpose, liquid ammonia is to be added to the fluid from which the silex is separated. The precipitate obtained is alumine, provided no metallic oxid was present. The former process, however, is

preferable. The demerits of the latter will be pointed out hereafter; for, although ammonia is a very good test to detect the presence of alumine, it cannot be used to ascertain the quantity of this earth when present in an acid solution.

EXAMPLE I.—*Analysis of the Saxon Hydrophan, or Occulus Mundi.**

Process I.—One hundred grains of the Saxon hydrophan were coarsely bruised, and ignited in a retort. At the end of this process there appeared, in the receiver, an empyreumatic water, covered with a thin pellicle. The loss of weight was $5\frac{1}{4}$ grains.

II.—The stone, thus freed from water, was triturated to a subtle powder, mixed with twice its weight of soda, and fused in a silver crucible in a moderate heat for two hours. When the mass had cooled, it was super-saturated, and digested with muriatic acid to separate the silex. The muriatic solution being separated from the siliceous earth, together with the water em-

* Klaproth's Analytical Essay, vol. I. p. 443.

ployed for washing it, was concentrated by evaporation, and saturated with ammonia; by which means a precipitate was produced, consisting of alumine, unmixed with iron, weighing $1\frac{5}{8}$ grains after ignition. Nothing farther was found in the remaining fluid.

One hundred parts of this hydrophane, from Saxony, therefore contain:

Silex	93,125
Alumine	1,625
Empyreumatic water	5,250
	100

EXAMPLE II.—*Analysis of the Transparent Chinese Agalmatolite, or Pagodite.*

Process I.—Two hundred grains of this stone finely pulverised, lost 11 grains of weight on being moderately ignited for half an hour.

II.—One hundred grains of this stone, freed from water were mixed with equal parts of carbonate of soda, and again subjected to a red heat for half an hour in a silver crucible. The

mixture was diluted with water, and super-saturated with muriatic acid, which dissolved the whole without leaving any residue. But when the solution had been put in a sand-heat to evaporate, it formed a thick gelatinous mass; after digesting it for some time, it was filtered. The collected siliceous earth, washed and ignited weighed 105½ grains.

III.—The muriatic solution, freed from its silex, being saturated with potash, thickened to a milk-white mass; which, by a slight excess of alcali, again dissolved entirely to a limpid, colourless fluid, leaving only a few light, brown, loose flocks behind, weighing four grains.

IV.—These four grains of brown residue were digested with muriatic acid. Siliceous earth, weighing 2½ grains in the ignited state, was thus separated. This being done, the solution was next combined with prussiate of potash, and the blue precipitate produced collected; the portion of iron, which it contained, amounted to 1½ grains. Nothing else was found in the remaining fluid.

V.—The alcaline solution, process III. being saturated in excess, with sulphuric acid, and decomposed, at a boiling heat, with sub-car-

bonate of soda, yielded a precipitate, consisting of alumine. This alumine being purified by acetic acid, (see analysis of argillaceous stones) after being dried, weighed 72 grains. Hence 100 parts of the stone contain

Alumine, process	V.		36
Silex	II.	52,$\frac{3}{4}$	54
	IV.	1,$\frac{1}{4}$	
Oxid of Iron	IV.		0,75
Water	I.		5,50
			96,25

GENUS III.—*Analysis of Siliceous Stones composed of Silex, Alumine, and Lime.*

Process I.—Fuse the levigated stone with potash.

II.—Dissolve the alcaline mass in water, and decompose it by muriatic acid to obtain the silex, as stated before.

III.—Digest the residue, which resisted the action of the alcali, in muriatic acid.

IV.—Mingle the obtained muriatic solution with the fluid from which the silex has been

separated; concentrate it by evaporation, and decompose it by the admixture of carbonate of potash. This precipitate consists of alumine and lime.

V.—To separate the alumine, boil the precipitate in a solution of potash, see page 336, and obtain the alumine, as stated, process IV. and V. &c. page 337.

VI.—To ascertain the quantity of lime, dissolve the insoluble part, left in process V. in muriatic acid, mingle the fluid with sulphuric acid in excess, and evaporate the mixture to dryness. The obtained compound is sulphate of lime.

VII.—To ascertain the quantity of lime, digest the product obtained in process VI. in water, decant the fluid, dry the sulphate of lime, and lastly expose it to a dull red heat, weigh it, and deduct from it 59 per cent. the remainder gives the quantity of lime which was present in the stone.

Example 1.—*Analysis of the Opake Chinese Agalmatolite, or Pagodite.*

Process I.—Two hundred grains of the stone

finely scraped off from the mass, suffered a loss of 20 grains by ignition.

II.—This ignited powder was a second time exposed to red heat for half an hour, in a silver crucible, with its own quantity of dry carbonate of soda, which caused it to agglutinate. The mixture, previously drenched with water, was combined with an excess of muriatic acid, and evaporated slowly till it assumed a gelatinous appearance. When this had again been diluted with water, it deposited silex, amounting to 122 grains, when collected on filtering paper, and subsequently washed and ignited.

III.—The muriatic solution was decomposed by carbonate of potash, and the thorough separation of the precipitate was promoted by boiling. The precipitate which subsided in a highly porous state, was washed, and while yet moist, transferred into a warmed solution of potash, in which it dissolved instantly, and left only a slight brownish residue.

IV.—Muriatic acid entirely dissolved this brownish residue, and by combining it with prussiate of potash, Prussian blue fell down, the quantity of which denoted one grain of iron in the stone.

V.—The fluid, after the separation of the

iron, was decomposed in a boiling heat with carbonate of potash, which precipitated a white earth, which effervesced with sulphuric acid, and deposited gypsum; the quantity of which increased, in proportion as the volume of the mixture was reduced by evaporation. It weighed, after ignition, five grains, equal to two grains of pure calcareous earth in the ignited state. The small quantity of the fluid yet remaining yielded crystals of sulphate of alumine.

VI.—The portion which had been taken up by the alcaline lye, process III. was precipated by sulphuric acid, but it dissolved again by a slight excess of sulphuric acid. The alum last obtained in process IV. was then added to it, and the whole precipitated by carbonate of potash, assisted by a boiling heat. When afterwards washed, dried, purified by means of acetous acid,* and finally heated to redness, the precipitated alumine weighed 50 grains.

VII.—The obtained alumine was then covered with sulphuric acid, and the mixture evaporated to perfect dryness. The turbidness of the fluid, on being again dissolved in water, was caused by a portion of siliceous earth, which separated, and

* See Analysis of Argillaceous Stones.

consisted of two grains after ignition. This being subtracted, the quantity of alumine, process V. is reduced to 48 grains; which now, by combination with acetite of potash, and crystallization, continued to the end to yield alum only.

It follows, from this decomposition of the Chinese agalmatolite, that its constituent parts give in the hundred:

Silex	Process $\left\{\begin{matrix}\text{II.} & 61\\ \text{VI.} & 1\end{matrix}\right\}$		62
Alumine	VI.		24
Lime	IV.		1
Oxid of iron	IV.		0,50
Water	I.		10
			97,50

Example 2.—*Analysis of the Stone called Cat's Eye.*

Process I.—Two hundred grains of the finely levigated stone were mixt with 400 of carbonate of soda, and exposed in a silver crucible to ignition for four hours. The mass was softened with water, saturated in excess with muriatic

acid, and the siliceous earth separated in the usual manner: it weighed 189 grains.

II.—The muriatic solution, mixed with the water, employed for washing the silex, was concentrated by evaporation, and saturated while yet hot with carbonate of soda; the precipitate, when dried, weighed 15 grains.

III.—The obtained precipitate entirely dissolved, with effervescence, in muriatic acid.—Only a slight portion of silex remained, which after being ignited amounted to one grain.

IV.—After the grain of silex had been separated, liquid ammonia was added to the solution. A yellowish-white precipitate was thrown down; which being separated by filtration, washed and boiled, while yet moist in caustic potash, left behind oxid of iron, weighing one half grain.

V.—The alcaline solution, process IV. was mixed with muriatic acid, and the precipitate being re-dissolved by a slight excess of acid, it was again precipitated by carbonate of soda.—When washed, and dissolved in sulphuric acid, it yielded crystals of alum. This sulphate of alumine was dissolved in water, and again precipitated by carbonate of soda. The alumine, when washed and ignited, weighed three grains and a half.

VI.—The fluid which remained, after the precipitation had been effected by ammonia, process IV. was combined in a warm temperature with carbonate of potash, by which means carbonate of lime subsided, which formed selenite (sulphate of lime) when covered with sulphuric acid, see page 311. The lime separated weighed three grains

Since, therefore, 200 grains of this stone afforded

Alumine, process	V.		$3\frac{1}{2}$
Silex	I. / III.	189 / 1	190
Lime	VI.		3
Oxid of iron	IV.		$\frac{1}{2}$
			197 grs.

It follows, that it contains in one hundred,

Silex	95
Alumine	1,75
Lime	1,50
Oxid of Iron	0,25
	98,50
Loss	1,50
	100

GENUS IV.—*Analysis of Siliceous Stones containing silex, magnesia and lime.*

Process I.—Fuse one part of the finely levigated stone with 3 or 4 of potash, as directed, process II. page 324.

II.—Dissolve the alcaline mass in water, and separate the silex by muriatic acid, see process III. page 325 and 326.

III.—Digest the insoluble matter left in process II. in muriatic acid, mingle the obtained solution with the fluid from which the silex has been separated, and evaporate the whole nearly to dryness.

V.—Cover the mass with sulphuric acid, evaporate the mixture, and lastly, heat it till no more fumes rise. This mass consists of sulphate of lime and sulphate of magnesia.

VI.—To separate the sulphate of magnesia pour a small quantity of water on the dry mass, and digest it for a few minutes, the sulphate of magnesia will become dissolved, and the sulphate of lime will be left behind.

VII.—To learn the quantity of magnesia, decompose the solution of this salt, obtained in process VI. by carbonate of potash, dry the pre-

cipitate, and expose it to a red heat for about half an hour, or till it dissolves in dilute muriatic acid without effervescence.

VIII.—To learn the quantity of lime, dry the sulphate of lime, (process VI.) expose it to a dull red heat, and weigh it. 59 per cent. being deducted from it, the remainder gives the quantity of lime.

Genus v.—*Analysis of Siliceous Stones composed of Silex, Alumine, and Barytes.*

Process I.—Fuse one part of the stone with potash, dissolve the mass in water, and separate the silex, as directed before, by muriatic acid.

II.—Dissolve the insoluble mass, left in process I. with muriatic acid; mingle the solution with the fluid from which the silex has been obtained, and decompose the mixture by carbonate of potash: this precipitate consists of carbonate of alumine and carbonate of barytes.

III.—Re-dissolve the mixt precipitate in muriatic acid, and drop into it sulphate of potash, or sulphuric acid, till no farther cloudiness ensues. The obtained precipitate is sulphate of barytes.

IV.—Boil the sulphate of barytes, with four or five times its weight of carbonate of potash in a sufficient quantity of water, for at least two hours, supplying the water as it evaporates. By this means a double exchange of principles takes place, the sulphuric acid of the barytes joins to the potash, and forms sulphate of potash, which is kept in solution; and the carbonic acid of the carbonate of potash goes to the barytes forming carbonate of barytes, which remains at the bottom. If this artificial carbonate of barytes be exposed to a violent heat, its carbonic acid will be disengaged, and the barytes be left behind in a pure state.

V.—To ascertain the quantity of alumine, evaporate the fluid from which the sulphate of barytes has been separated, process III. to a small compass, decompose it by carbonate of potash: the precipitate obtained is carbonate of alumine.

VI.—Boil this precipitate in a solution of potash or soda, and decompose the alcaline solution by muriatic acid: the precipitate obtained is alumine.

For some farther particulars with regard to the separation of alumine from lime and magnesia,

the reader is referred to the analysis of argillaceous stones, and to page 336.

GENUS VII.—*Analysis of Siliceous Stones composed chiefly of Silex and Alumine, with a portion of an Alcali.*

For the following easy and expeditious method of analysing stones, containing an alcali in combination, we are indebted to Mr. Davy.*

Process I.—Let one hundred grains of the stone finely levigated be fused in a platina or silver crucible for half an hour, in a strong red heat, with 200 grains of boracic acid.

II.—Digest the fused mass in $1\frac{1}{2}$ oz. of nitric acid, diluted with 7 or 8 times its quantity of water, till the whole is decomposed; concentrate the fluid, by which means the silex will become separated, if any was present; let it be washed with water, to free it from the adhering boracic acid, and saline matter.

III.—Evaporate the fluid from which the silex has been separated to about 16 cubic inches or less; drop into it a solution of carbonate of ammonia in excess, and boil the mixture

* Philosoph. Trans. Part II. 1805.

ture for a few minutes; and then separate the insoluble part. By this means all the earths and metallic oxids that were present in the stone are separated.

IV.—Let the fluid next be mingled with nitric acid till it tastes strongly acid, and again evaporate it till the whole of the boracic acid is separated; nothing now remains but the nitric acid in combination with the alcali of the mineral, and with ammonia.

V.—To free the mass from the nitrate of ammonia, let it be evaporated to dryness, and expose it to a heat of about 500, the nitrate of ammonia will be decomposed, and become volatilized in the gazeous state, and the nitrate of potash or soda remain behind in the vessel.

VI.—To obtain the alcali in a pure state, the nitric acid may be driven off by exposure to a dull red heat. To learn whether the alcali be potash or soda, drop into its solution in water, muriate of platina, which will occasion a buff or orange-coloured precipitate with potash, but not with soda.

The remaining earth, viz. the alumine, may be separated as stated before.

Remark.—The presence of potash in a stone

containing alumine may also be detected by boiling the finely powdered mineral repeatedly to dryness, with concentrated sulphuric acid, then washing the dry mass with water, adding to it a little excess of acid; and, lastly, evaporate the solution to a small bulk. If crystals of alum should appear, it is a proof of potash, because this salt can never be obtained, in a crystallized form, without the addition of this alcali.

But, since a stone may contain potash, and a little or no alumine, in which case no crystals of alum can be formed, it is necessary, in the latter case, to add a portion of alumine to the sulphuric acid. Or the mineral may be so hard as to resist the action of sulphuric acid; it will then be necessary to fuse it (in the manner directed before,) with soda. The fused mass is to be dissolved in water, and supersaturated with sulphuric acid. It should next be evaporated to dryness, re-dissolved in water; and filtered, to separate the silex. The solution on being evaporated affords crystals of sulphate of soda, and afterwards crystals of sulphate of potash, should the latter alcali be contained in the mineral.

Klaproth first discovered potash in the leucite. On summing up the results of its first analysis,

he found that there appeared to be a considerable loss of weight, and by boiling the stone with diluted muriatic acid, and evaporation, he obtained crystals of muriate of potash.—Another proof of the presence of potash was, that, when sulphuric acid was boiled with it, the solution gave crystals of alum, to which potash is essential. He also boiled the stone with muriatic acid, and, after dissolving the muriate of alumine by alcohol, muriate of potash remained. The leucite contained less potash than other kinds. The same alcali has also been detected in lepidolite, and in several other stones.

The potash contained in sulphate of alumine, may be separated from the earth by adding a solution of barytes as long as any precipitate is produced. The alumine and sulphate of barytes will fall down together, and the potash remain in solution. Its presence may be known by the tests, already stated.

Soda may be detected in a mineral by the following experiments: Let the powdered stone be treated with sulphuric acid, as stated before; wash off the solution, and add pure ammonia till the precipitation ceases; then filter, evapoporate the solution to dryness, and raise the heat so as to expel the sulphate of ammonia:

The sulphate of soda will remain, and may be known by its characters.

We shall conclude this subject by giving the analysis of several minerals containing an alcali, as performed by Klaproth.

Example 1.—*Analysis of Cryolite.*

Process I.—Sixty grains of cryolite finely levigated, were mixed in a platina bason with 120 grains of sulphuric acid, covered with a pane of glass, which had a thin coating of wax and characters traced through it. Very soon fluoric acid vapours arose, by which, after 12 hours, the uncovered glass was found etched to a considerable depth. The mass was upon this diluted with water, and evaporated to dryness. When the remaining saline mass, had again been mixed with water and filtered, a white earth was left on the paper.

II.—The obtained solution, on being again evaporated, yielded, as before, a crystallized saline mass; but as a portion of uncombined sulphuric acid still adhered to it, it was separated by the affusion of alcohol, which being decanted and combined with liquid ammonia, let fall another slight quantity of earth. This,

together with that before obtained, was dissolved in sulphuric acid.

III.—The concrete salt, that has been washed with alcohol, was re-dissolved in water, and suffered to evaporate spontaneously. It yielded regular clear crystals, weighing 18½ grains, which were found to be sulphate of soda. The remainder of the solution coagulated in the open air into an irregular, small-grained saline mass, which, being dissolved in water, was mixed with the above-mentioned solution of earth in sulphuric acid, process II. then precipitated with carbonate of ammonia, and filtered. The precipitated earth, being washed, was entirely soluble in a solution of soda, poured on it whilst yet moist. After this solution had been again neutralized by sulphuric acid, it was decomposed by carbonate of potash. The obtained precipitate being re-dissolved in sulphuric acid, and combined with a proper proportion of potash, yielded crystallized sulphate of alumine.

IV.—The fluid from which the alumine had been obtained by carbonate of ammonia, was first neutralized with acetic acid, and then precipitated by acetate of barytes. The filtered solution was evaporated to dryness, and lastly, heated to redness in a platina crucible. The

melted saline mass being rendered blackish from the admixture of coal, was again dissolved in water, and freed by filtration from the coaly particles. It was then evaporated, and yielded 26 grains of dry carbonate of soda. This salt, saturated with nitric acid, yielded regular rhomboidical crystals of nitrate of soda, weighing 40 grains.

"Thus have I," says Klaproth, "besides the two constituent parts of cryolite mentioned by Abildgaard, unexpectedly found soda as its third essential constituent part. My satisfaction occasioned by this discovery was heightened by the circumstance, that cryolite is the first instance that came to my knowledge of a stone, in which soda is contained in a constituent part."

Mr. Vauquelin, who likewise has examined cryolite, suspects that, perhaps, during the decomposition effected by sulphuric acid, part of the aluminous ingredient is carried off along with the fluoric acid. In fact it would hardly be possible to explain, in what manner 28 per cent. of alumine, the quantity fonnd by Vauquelin in that fossil, should be capable of fixing such a quantity of fluoric acid as is necessary to make the neutral compound, which is generated by this combination, amount to 100 grains.—

However, this difficulty is removed by the presence of soda discovered in the mineral.

For the purpose of determining the proportions of the constituent parts of cryolite, Mr. Klaproth repeated its analysis in the manner, we shall now describe.

Process I.—To free 100 grains of cryolite, entirely from its fluoric acid, they were digested and evaporated to dryness in a platina crucible with 300 grains of concentrated sulphuric acid. The mixture boiled at first, emitting fluoric acid vapours and numerous air-bubbles. The residue, previously drenched with water, gelatinized on evaporation to a soft, granular saline mass, which readily became soluble in a little water.

II. Liquid ammonia precipitated from the clear solution the alumine earth which weighed 46 grains when edulcorated and dried, but 24 when ignited. The solution of this earth, in dilute sulphuric acid, with the assistance of heat, and combined with a proper proportion of pot-ash, yielded regular crystals of alum.

III. The fluid, from which the alumine had been precipitated by ammonia, was first neutralized with acetic acid, then combined with acetate of barytes, and filtered to separate the sulphate

of barytes. The clear fluid was now wholly evaporated; the dry residue, after being ignited in a platina crucible, was re-dissolved, and being rendered free, by filtration, from the few adhering coaly particles, was a second time evaporated to perfect dryness. It thus afforded 62 $\frac{1}{2}$ grains of dry carbonate of soda, equal to 36 grains of soda. This product being saturated with acetic acid, yielded crystallized acetate of soda.

If we now from the quantity of the fossil employed, subtract the weight of alumine and soda obtained, the remainder will give the weight of the fluoric acid, including, perhaps, the water of crystallization. One hundred parts of cryolite, therefore, consist, according to this analysis, of

Soda	36
Alumine	24
Fluoric acid, including water	40
	100

Example 2.—*Analysis of Sonorous Porphyry.*

This stone is also called Klingstone, or Echodolite, or Phonalite, was accomplished by Klaproth thus:

Process I.—One hundred grains of the finely powdered stone, were mixed with a solution, or

lye, containing 250 grains of pot-ash, when inspissated and ignited in a silver crucible. It acquired at first a blackish colour, which afterwards disappeared. The ignited mass was greenish, it was softened with water; muriatic acid was added in excess, it dissolved the whole, and afforded a clear solution. This solution assumed a greenish appearance on evaporation to drynes: the dry mass was re-dissolved in water sharpened with a little muriatic acid, and the siliceous earth separated in the usual manner. It weighed $57\frac{1}{4}$ grains.

II.—The muriatic fluid was mingled with liquid caustic ammonia, the obtained precipitate was of a light brown colour, the excess of ammonia in the remaining fluid, first neutralized with muriatic acid, yielded a slight precipitate by oxalate of ammonia, which, collected and exposed to a strong red heat, left $2\frac{1}{4}$ grains of carbonate of lens.

III.—The light brown precipitate, process II. was transferred into a boiling solution of pot-ash. It soon was taken up, leaving a residue of blackish brown flocks, which were collected on a filter. The solution, when supersaturated with muriatic acid and precipitated with carbonate of ammonia, yielded carbonate of alumine earth,

which, dried and ignited, weighed $23\frac{1}{2}$ grains; and when combined with sulphuric acid and pot-ash, yielded pure acedulous sulphate of alumine.

IV.—The residue, left un-dissolved by the solution of pot-ash, yielded with muriatic acid a yellow tincture. This solution was perfectly neutralized, and then decomposed with succinate of soda. The succinate of iron obtained, after being ignited, amounted to $3\frac{1}{4}$ grains.

V.—The residue of this yellow fluid, process IV. was examined with carbonate of ammonia. This alcali threw down another small portion of a yellowish white earth, which became black after ignition: it weighed $\frac{3}{4}$ grain. On being dissolved in a few drops of muriatic acid, and combined with sulphuric acid, it yielded sulphate of lime. That small portion, which remained of it, being combined with ammonia, then evaporated and ignited, left an oxid of manganese behind, which imparted a clear amethyst colour when fused with phosphoric acid. The mentioned $\frac{3}{4}$ of a grain may be estimated at $\frac{1}{2}$ grain of lime, and $\frac{1}{4}$ grain of oxid of manganese.

Finding, that the sum of the products, obtained in this decomposition, was by far too short of the weight of the mineral employed, and thus shewed that another constituent part was to be

sought for, the following experiment was again undertaken.

VI.—Upon 300 grains of the stone, finely triturated, were poured, in a retort, 600 grains of sulphuric acid, diluted with an equal quantity of water; the whole was digested for a while: and lastly, the fluid distilled over to moderate dryness. The fluid in the receiver was poured back upon the residue a second time, digested, and again abstracted by distillation. The mass left in the vessel was softened by boiling water, the fluid filtered; the obtained residue washed, dried, and ignited. It weighed 258 grains. As the merely silicious part would have given no more than 171$\frac{3}{4}$ grains; it was evident, that the sulphuric acid had been incapable of effecting a thorough decomposition of the stone: as also could well be inferred even from the little change the residue had undergone.

VII.—On concentrating by evaporation, the sulphuric solution, there appeared 10$\frac{1}{2}$ grains of sulphate of lime in thin needles; which, being removed, the evaporation of the saline fluid was continued with a gentle heat to the point of crystallization; but the crystals formed on cooling, were unlike the crystals of alum.

VIII.—These crystals being re-dissolved in water, the solution was mixt with the fluid that remained after the crystallization, and the whole precipitated with ammonia. When the brown precipitate had been filtered off, the clear fluid was evaporated to dryness. The obtained mass was exposed to a heat of so high a degree that the sulphate of ammonia was volatilized. A salt of 22 grains weight remained behind, which was sulphate of soda.

However, since by this treatment with sulphuric acid the fossil was found but partially decomposed, and therefore, the proportion of the soda could not exactly be determined, the following experiments were made:

IX.—One hundred grains of the levigated stone were mixed by trituration, with 400 grains of crystallized nitrate of barytes, and in a capacious vessel exposed to a heat gradually raised to ignition.

X.—The fused mass being suffered to cool, was pale blue, spongy, and easily pulverizable. When softened with water and treated with muriatic acid it dissolved entirely, yielding a clear, yellow solution. This solution was evaporated, and at the same time gradually combined with as much sulphuric acid as was

necessary not only to precipitate the barytes in the state of sulphate of barytes, but also that the same acid, after the total expulsion of the muriatic acid, continued notably predominant in the fluid.

XI.—Having reduced the saline mass to a moderate dryness, it was again diffused through water: the insoluble part consisted of sulphate of barytes and the siliceous ingredient of the stone. The fluid was mingled with ammonia, the precipitate obtained was filtered off, the neutralized liquor evaporated to dryness, and then kept in a moderately intense heat, until all the sulphate of ammonia was driven off. The remaining portion when dissolved in water and crystallized, proved to be pure sulphate of soda. This was again dissolved, and decomposed with acetate of barytes; the precipitated sulphate of barytes was separated, the filtered clear fluid evaporated, and the dry acetate of soda heated to redness in a platina crucible. The coaly residue gave by solution in water and filtration, a clear, colourless fluid, which upon evaporation to dryness left 14 grains of carbonate of soda, of which the portion of soda makes $8\frac{1}{10}$ grains. This,

when neutralized with nitric acid, yielded crystals of nitrate of soda.

" Yet it may be fairly supposed," says our author, " that, in the natural composition of the stone, the soda exists in a somewhat greater proportion than is indicated by the quantity obtained. For, besides that in general some loss is unavoidable in the different operations, I think that already at the ignition of the barytes a certain portion of the soda is volatilized: which to suppose I am induced to believe from the vapours which visibly escape in a filamentous form on removing the lid of the vessel.

After these operations we now return to the results of the analysis. These then give the constituent parts and their proportions in the hundred, as follows:

Silex	process I.	57. 25
Alumine	III.	23. 50
Lime	II. 2. 25; V. 0. 50	2. 75
Oxid of Iron	IV.	3. 25
Oxid of Manganese.	IV.	0. 25
Soda	XII.	8. 10
	Loss	5. 5
		98. 10

"The reflecting natural philosopher will know, without our suggesting it, how to appreciate the value of this discovery of the presence of soda, as a constituent part, in a stone which occurs in masses of the size of whole mountains. It opens to him a new view, and leads him a long step farther in his geological inquiries. We now see that there is no longer any occasion for the theory hitherto prevailing, according to which it was imagined necessary to consider all the soda, which in nature occurs either in a free, that is uncombined, or in a carbonated state, arising from a decomposition of common salt, or of sea salt, or of that from saline springs, supposed to have been carried on by nature, and to have taken place in an unknown manner."

The sonorous porphyry, employed in the preceding experiments, was obtained from the Donnersberg, near Milleschau, the highest of the middle mountains in Bohemia. The whole mass of this majestic mountain, which is above two thousand five hundred feet high, extending to many square miles, absolutely consists only of this very stone.

If we reflect, that in this enormous mass of rock, the soda constitutes nearly the twelfth part

of the whole mountain, it will not be thought an exaggeration to say, that this mountain alone is capable of supplying for a long succession of years to come, all Europe with a sufficient quantity of soda; presupposing however, that experiments should be devised to separate this alcali from the stone by a cheap and profitable method, and which there is reason to hope the brilliant experiments of the decomposition of alcalies, lately discovered by Davy, will soon be accomplished.

Example 3.—*Analysis of the Pitchstone.*

Process I.*—One hundred grains of pitchstone from Meissen, in coarse fragments, were heated to redness for thirty minutes, in a covered crucible. They returned from the fire of a white-grey, marbled with yellow, opake, and of a meager and rough feel, though they had naturally an appearance of glazing. They lost $8\frac{1}{2}$ grains in weight.

II.—One hundred grains of this finely pulverized pitch stone were mingled with a solution of 200 grains of soda, and the mixture evaporated in a silver crucible, and kept for half an hour

* Klaproth's Analytical Essays, vol. II. p. 205.

in a moderately strong red heat. The mass was white, inclining to bluish. After being softened with water and saturated in excess with muriatic acid, 73 grains of silex were obtained in the usual manner.

III.—The muriatic solution from which the silex had been obtained, was mixed in excess with soda, and digested in a heat of ebullition. In this process most of the precipitate formed at the beginning, again became dissolved; yet leaving a brown insoluble residue. This being separated, the alcaline fluid was neutralized with muriatic acid, and precipitated with carbonate of soda. The alumine of which the precipitate consisted, was weighed, dried, and ignited. It amounted to 14½ grains. The whole of it combined with sulphuric acid and potash, yielded crystals of alum.

IV.—That small portion of the precipitate, which was left undissolved by the alcali, process III. was first dissolved in muriatic acid, and then combined with sulphuric acid. Sulphate of lime was generated, which was collected and washed with weak alcohol. The filtered fluid being again reduced to a smaller compass by evaporation, and then combined with sulphuric acid, yielded another small portion of sul-

phate of lime. The quantity of this together with the first, weighed three grains, which indicate one grain of lime.

V.—The fluid, being now freed from lime the portion of iron which it yet contained was precipitated by carbonate of ammonia. It weighed one grain. The remainder of the fluid was evaporated to dryness; and on re-dissolving the saline mass in water, oxid of manganese separated in fine, minute flocks, the slight quantity of which could not be estimated higher than $\frac{1}{10}$ grain.

IV.—Having so far proceeded, one hundred grains of pulverized pitch stone were mixed with 300 grains of nitrate of barytes in crystals, and ignited in a porcelain vessel till the nitrate had been entirely decomposed. The mass being softened in water, was first neutralized with muriatic acid, and then combined with sulphuric acid in such a proportion, that the latter, on evaporating the mixture, and after the muriatic acid had been expelled by heat, remained still preminant. The evaporated mass was washed with hot water, the residuum separated by filtration, and the clear fluid saturated with carbonate of ammonia added in excess. After the precipitate produced by this means, had been separated

the fluid was reduced to a dry salt by evaporation, and its portion of sulphate of ammonia volatilized in a porcelain vessel exposed to a moderate heat. A salt thus remained, consisting sulphate of soda. This being re-dissolved and decomposed by acetate of barytes, the filtered solution was evaporated to a red heat in a platina crucible. The saline residue being re-dissolved, filtered, and again evaporated to dryness, gave three grains of carbonate of soda, amounting to $1\frac{3}{4}$ grains of soda; which neutralized with nitric acid, yielded the usual rhomboidal crystals of nitrate of soda.

Therefore, one hundred grains of this pitch stone from Meissen consist of:

Silex	process II.	73.
Alumine	III.	14. 50
Lime	IV.	1.
Oxid of Iron	V.	1.
Oxid of Manganese	V.	0. 10
Soda	III.	1. 75
Water	I.	8. 50
		99. 85

Example 4.—*Analysis of Pumice Stone.*

Process I.—One hundred grains of finely pulverized pumice stone, were mixed with 300 grains of crystallized nitrate of barytes, and the mixture exposed to an intense red heat, till the nitrate of barytes was compleatly decomposed.

II.—The ignited mass was powdered, drenched with water, dissolved in muriatic acid, supersaturated with a sufficient quantity of sulphuric acid, and evaporared to dryness.

III.—The mass was elixiviated with water, passed through the filter, the clear sulphuric solution decomposed with carbonate of ammonia, and the precipitate collected on the filter.

IV.—The fluid from which the precipitate was obtained was a second time evaporated, and the remaining dry salt ignited till the sulphate of ammonia had been entirely driven off. There remained a fixed neutral salt.

V.—This product was dissolved in water; the solution decomposed by acetate of barytes, the fluid after separating the produced sulphate of barytes, was evaporated to dryness, and the residue exposed to a strong red heat. On a subsequent solution in water, filtration and eva-

poration to dryness, there remained five grains of a carbonate of soda, which being saturated with nitric acid yielded nitrate of soda. For those 5 grains of carbonate of soda, 3 grains of pure soda must be put in the account.

But as the figure of the crystals of nitrate of soda seemed to pass into prisms they were dissolved in a little water, and mingled with a saturated solution of tartareous acid. A notable quantity of acidulous tartrite of potash deposited in small grains, which shewed that the obtained soda was contaminated with potash.

To determine the proportion of potash to that of soda in pumice stone, was not well practicable in this experiment, on account of the small quantity.

However, by the result from this experiment the sum of the constituent parts of pumice stone was rendered more complete, namely:

Silex	77. 50
Alumine	17. 50
Oxid of iron, and a little magnesia	1. 75
Soda and Potash	3.
	99. 75

Example 5.—*Analysis of Basalt.*

In the chemical decomposition of basalt, undertaken by Klaproth, the principal design was to ascertain whether this stone, was geognostically allied with the sonorous porphyry, and whether like this it contains soda as a constituent part.

Process I.—For this purpose, one hundred grains of levigated basalt were mixed with 400 grains of nitrate of barytes, and treated in the same manner as has been stated before: $4\frac{1}{2}$ grs. of dry carbonate of soda were obtained, which are equal to 2,60 grains of soda. The other constituent parts Klaproth proved in the following manner:

II.—One hundred grains of pulverized basalt were ignited, for two hours, with 400 grains of carbonate of soda, at a degree of heat at which the mixture would not fuse. It agglutinated into a moderately hard yellow mass, which being powdered, and softened in water, was neutralized with muriatic acid, next supersaturated with nitric acid, and evaporated to dryness. The dry mass, which had a yellow colour, was diffused through water a little acidulated

with muriatic acid, and after a short digestion filtered. The silex obtained weighed, after ignition, 44½ grains.

III.—The muriatic solution was precipitated at a temperature of 212° Fahr. by carbonate of soda. The obtained precipitate was digested with a solution of soda, and the residue separarated by filtration. The alcaline fluid, when combined with muriatic acid, added in a small excess, was precipitated with carbonate of ammonia. By this means alumine fell down, amounting to 16¾ grains, when washed and ignited: and yielding alum when treated with sulphuric acid and potash.

IV.—The brown residue of process II. was dissolved in muriatic acid, carefully watching the precise point of saturation, and to the solution was added succinate of ammonia to precipitate the iron. The obtained succinate of iron, when washed and ignited, gave 20 grains of oxid of iron attractable by the magnet.

V.—The fluid, thus freed from iron, was treated, in a boiling heat, with carbonate of soda. The white precipitate produced was dissolved in nitric acid, and the solution combined with sulphuric acid, which threw down a considerable quantity of sulphate of lime. This

being separated, the remainder of the fluid was evaporated almost to dryness, again diluted with a mixture of water and spirit of wine, and the sulphate of lime then separated was added to the preceding. The sulphate of lime was next composed by boiling it with carbonate of soda; and the carbonate of lime thus obtained, washed and dried, weighed 17 grains, which indicate $9\frac{1}{2}$ grains of lime.

VI.—The fluid remaining from the last operation was mixt with soda, which occasioned a slimy precipitate: this was dissolved in sulphuric acid, and evaporated. At the first impression of heat, brown loose flocks fell down which left the solution colourless. These flocks, separated by filtration, proved to be oxid of manganese; yet their slight quantity permitted only an estimation by guess at about $\frac{1}{8}$ grain.

VII.—The small quantity that yet remained of the fluid was evaporated to dryness, and the residue exposed in a crucible to a strong red-heat. This, being re-dissolved in water, left another slight portion of alumine, tinged by iron, and contaminated with manganese, weighing $\frac{1}{2}$ grain; but the clear solution entirely crystallized into sulphate of magnesia. The earthy base of this salt, precipitated in the car-

bonated state by carbonate of soda, weighed 6 grains; for which must be accounted $2\frac{1}{4}$ grains of magnesia.

From this analysis of the basalt result the following constituent parts:

Silex	process II.	44. 50
Alumine	{III. IV.}	16. 75
Oxid of Iron	V.	20.
Lime	V.	9. 50
Magnesia	VII.	2. 25
Oxid of Manganese	VI.	0. 12
Soda	I.	2. 60
Water	I.	2.
		97. 72

With these results pretty well agree those of the analysis which Bergmann has published in his valuable dissertation, *De productis vulcanicis*, namely:

Silex	50
Alumine	15
Lime	8
Iron	25
Magnesia	2
	100

Though Bergmann mentions the lime in the carbonated state, yet he has omitted to prove that it is contained as such in the composition of basalt. But what concerns the soda, it is no matter of wonder that it has escaped his attention, since at that time it could not be suspected that this alcali should one day appear in the state of an essential constituent part of solid stones.

TABULAR ARRANGEMENT

OF

SILICEOUS STONES,

ACCORDING TO THEIR CHEMICAL COMPOSITION AND EXTERNAL CHARACTERS.*

Siliceous Stones composed of Silex nearly in a state of purity.

Crystallized quartz, or rock crystal
Purple quartz, or amethyst
Blue quartz, occidental saphir, or water saphir
Smoky quartz, or cairn gorum crystal
Black quartz
Blood-red quartz, or compostella hyacinth
Phrase, or green quartz

* For the external characters of these, and the rest of the mineral substances mentioned in this Essay, the reader is referred to the author's System of Mineralogy.

Chrysophrase
Rose, or milk quartz
Iridiscent quartz
Spangled quartz, or avanturine
Compact, or common quartz
Fibrous quartz
Hialin quartz

Siliceous Stones containing a considerable portion of Alumine.

Chalcedony
Cocholong, or milk white chalcedony
Iridescent cocholong
Onix
Sardonix, or red striped onix
Agate
Landscape agate
Ribbon agate
Moss agate, or mocha stone
Tube agate
Star agate
Clouded agate
Coral agate
Jasper agate
Punctuated agate
Agatized wood

Jasper
Egyptian jasper, or Egyptian pebble
Opal jasper
Striped, or banded jasper
Opal
Noble opal
Hydrophan opal
Semi opal
Wood opal
Jasper opal
Hyalite, or Muller's glass
Menelite
Cat's eye
Heliotrop, or blood-stone
Carnelian
Flint
Jasper flint
Pitchstone
Pimelite
Plasma
Hornstone petrosilex, or chert
Rhomboidal hornstone
Red hornstone
Hornstone porphyry
Woodstone, or agatized hornstone
Jasperized hornstone

Siliceous Stones containing Alumine and lime.

Zeolite
Mezotype, or radiated zeolite
Fibrous zeolite
Mealy zeolite
Lamellar zeolite, or stilbite
Analcime cubicite, cubic zeolite
Lomoniti, or efflorescent zeolite
Aedilite, or siliceous zeolite
Crocolite
Paranthene, micarel, scapolite, rapidolite
Thalite, epidote, arandalite, delphenite, acanticone, acanticonite, pistacite, or strahlite
Scorza
Garnet
Noble garnet
Bohemian garnet, or pyrope, carbuncle
Common garnet
Topazolite
Alochroite
Dauorite
Zoisite
Yanite
Diopside
Bergmanite

Chusite
Fuscite
Gabronite
Limbelite
Petalite
Pseudo nepheline
Tabular spar
Succinite

Siliceous Stones containing a portion of magnesia, alumine, and lime.

Melanite, or black garnet
Dialage, smaragdite, or emeraldite
Schiller spar
Pistacite
Anthophilite
Malacolite, or sahlite
Pyroxene, augiti, volcanite, or black volcanic shorl
Amphibole, or hornblende
Common hornblende
Basaltic hornblende
Labrador hornblende
Shorlaceous hornblende
Meïonite

Siliceous Stones containing a portion of alcali, with alumine, silex, and lime.

Lepidolite
Leucite, or amphigene
Natrolite
Pumice stone
Andalusite, or mecaphilite
Retenite, or deadolite,
Pitchstone
Echodolite, or sonorous porphyry
Adularia
Common feldspar
Ichtyopthalmite
Obsidian
Vitreous obsidian
Black obsidian
Green obsidian
Pearlspar
Marekanite
Crysolite, cryolite, fluate of alumine and soda
Porcelain jasper
Basalt
Basaltic hornblende

ORDER II.

CALCAREOUS STONES.

Division of Calcareous Stones.

To this class of earths and stones belong all those minerals in which lime forms the most predominant, or most characteristic part. They may be divided in the following manner:

GENUS I.—*Native Carbonates of Lime; or Stones chiefly composed of Calcareous Earth united to Carbonic Acid.*

GENUS II.—*Sulphates of Lime; or Stones chiefly composed of Lime and Sulphuric Acid.*

GENUS III.—*Fluates of Lime; or Lime combined with Fluoric Acid.*

GENUS IV.—*Phosphates of Lime; or Stones chiefly composed of Lime united to Phosphoric Acid.*

Genus v.—*Borates of Lime.*

Genus vi.—*Arseniates of Lime.*

CHARACTERS OF CALCAREOUS STONES.

The totality of the characters peculiar to the class of calcareous stones, are chiefly the following: They do not scratch glass. They do not fuse with alcalies into a homogenous transparent mass. They do not fuse with glacial acid of phosphorous, or with boracic acid. They do not adhere to the tongue, nor do they form a kneadable mass when reduced to powder, and mixt with water. They can all be scratched with a penknife or steel point. Most of them are more or less acted on by , or are soluble in, nitric or muriatic acid, or are at least so after having been boiled with a solution of sub-carbonate of potash. Their neutral solution in acids are all decomposable by oxalates, and fluates of soda, potash, and ammonia, and the precipitate is insoluble in nitric or muriatic acids.

ANALYSIS OF CALCAREOUS STONES.

As it is impossible to point out a ready me-

thod which could be applicable to the examination of all stones of this genus, we shall consider them under two sections, namely:

1st.—*Calcareous stones which are readily soluble in nitric or muriatic acid, dilute with 3 or 4 parts of water, and with more or less effervescence.*

2dly.—*Calcareous stones which are not soluble in nitric or muriatic acid; or at least far more difficult, and which do not effervesce.*

To the first species belong all the stones properly called carbonates of lime, or lime-stones. They may be distinguished and analysed in the following manner:

ANALYSIS OF CALCAREOUS STONES WHICH ARE READILY SOLUBLE IN NITRIC OR MURIATIC ACID, AND WITH MORE OR LESS EFFERVESCENCE.

GENUS I.—*Analysis of Carbonates of Lime.*

The stones belonging to this division are wholly soluble in nitric or muriatic acid, with effervescence, or nearly so. They yield carbonic

acid gas when exposed to heat, and become converted into quick-lime.

They may be examined in the following manner:

Process I.—Take a weighed quantity of the stone reduced to an impalpable powder, digest it repeatedly, with a gentle heat, in muriatic acid, till this fluid exercises no farther action on it, which may be known by letting fall into the acid, that has been decanted, and rendered neutral by an alcali, a solution of carbonate of potash in excess; if no precipitate ensues, the digestion may be discontinued. The insoluble residue, if any, should be washed, dryed, and weighed.

II.—To the obtained muriatic solution add 20 times its bulk of water, and drop into an aliquot portion of it, a crystal of sulphate of soda or potash. If the stone contained barytes or strontia, or both these earths, a precipitate will ensue, if not, the solution remains transparent. The modes of ascertaining the quantities and proceedings of separating these earths, are unnecessary to be detailed here. They will be stated under the articles analysis of stones of the barytic and stontian genus.

III.—Add to the filtered solution, after being

made boiling hot, and from which the barytes or strontia has been separated, by means of sulphate of soda, a solution of sub-carbonate of soda, till no farther cloudiness ensues, collect the precipitate, wash and dry it, at least so much that it may be conveniently transferred from the filter.

IV.—The precipitate obtained in process III. may contain, besides lime, also a portion of magnesia and alumine. To separate the latter, boil the precipitate with a concentrated solution of potash or soda, in a silver bason, for at least one hour, supplying the water as it evaporates. The alumine will by this means become dissolved in the alcali, and the magnesia and lime will remain behind untouched.

V.—To ascertain the presence and quantity of alumine in the stone, mingle the alcaline solution with muriatic acid, till no farther precipitate ensues; decant the supernatant fluid, wash the precipitate, dry it, and lastly, ignite it for about half an hour. The product obtained, gives the quantity of alumine.

VI.—To ascertain the quantity of lime and magnesia, re-dissolve the precipitate, freed from its alumine, (process IV.) in muriatic acid;

evaporate the solution to dryness; weigh the dry mass, and pour over it, in a glass bason, more than twice its own weight of concentrated sulphuric acid; stir the mixture well together, heat it gradually, and increase the heat till the excess of sulphuric acid is expelled, or till no more pungent dense vapours are disengaged.

VII.—Digest the dry mass, previously levigated with a little alcohol, as fine as possible, in about twice its weight of cold water, which will dissolve the sulphate of magnesia, and leave the sulphate of lime. The latter may be separated by the filter, after having been repeatedly washed in small portions of water.

VIII.—To ascertain the quantity of magnesia, if any was present, heat the fluid obtained in process VII. to ebullition, and then drop into it a solution of carbonate of potash. The precipitate produced is carbonate of magnesia. Let it be ignited for about half an hour: what remains is magnesia.

IX.—To learn the quantity of lime, let the insoluble precipitate (the sulphate of lime, obtained in process VII.) be dried in a low red heat, weigh it, and then deduct from it 59 per cent. the remainder (viz. 41) gives the quantity of lime.

To ascertain the quantity of carbonic acid contained in the stone, introduce a weighed quantity of it into a bottle furnished with a spiral tube, and proceed according to the rules pointed out in the description of the plates.—See apparatus for easily ascertaining the quantity of carbonic acid contained in mineral substances.

The stones belonging to this class almost all contain more or less alumine and magnesia. The mode of analysis given is that usually employed, and answers well for ordinary enquiries. The most perfect separation of these earths from each other is nevertheless attended with considerable difficulty, as has been stated already in the preceding pages, and will be again considered under the analysis of argillaceous stones.

The presence of magnesia in lime stones having been lately found to prove extremely injurious to vegetation, when employed as a manure, we shall briefly notice that magnesian lime stone may readily be discriminated from that which is purely calcareous, and therefore fit for agriculture, by the extreme slowness of its solution in acids, which is so considerable that even the softest kind of the former is much longer dissolving than marble.

To ascertain, by chemical means, whether a lime stone be fit for agricultural, or architectural purposes, the following is the easiest, though not the most accurate, process.

Process I.—Put into a florence flask 100 grains of lime stone reduced to powder; and pour on it by degrees $\frac{1}{2}$ oz. of sulphuric acid, on each affusion of the acid a violent effervescence will ensue; when this ceases, stir the acid and lime together with a small glass rod, and heat the mixture over a lamp till it becomes dry.

II.—Reduce the mixture to powder, as far as possible, and pour over it 2 or 3 oz. of water; heat the mixture for about a quarter of an hour, and when cold transfer the whole on a filter, the weight of which has previously been ascertained. Wash the insoluble residue on the filter, by pouring over it small portions of water at a time, and add the water thus expended to the filtered fluid.

III.—To the before obtained solution add gradually $\frac{1}{2}$ oz. of sub-carbonate of potash, previously dissolved in about 2 or 3 oz. of water, which, if magnesia be present, will produce a very copious white precipitate; if not, a slight milkiness will ensue.

IV.—Heat the liquor (if magnesia be present) by setting it in a tea cup near the fire; let the precipitate subside; pour off the clear fluid, which may be thrown away, and wash the white precipitate with warm water, then pour it on a filter, the weight of which is known, dry and weigh the whole. The result shows how much carbonate of magnesia was contained in the original stone; or deducting 60 per cent. how much pure magnesia 100 parts of the lime contain. If burnt lime has been used, deduct from the weight of the precipitate 60 per cent. and the remainder gives the weight of magnesia in each 100 grains of burnt lime. We are indebted to Mr. Tennant for having first discovered the deleterious habitudes of the magnesian lime stone, when applied as manure in agriculture, and their unfitness for mortars and cements.—A correct drawing and description of this stone is given in Sowerby's British Mineralogy, No. XLIII. 1807.

ANALYSIS OF MARLS..

The name of marl is given to a mixture, chiefly composed of carbonate of lime and clay, in which the carbonate considerably exceeds the

other ingredients. In agriculture the following varieties are chiefly distinguished: viz.

Common Marl, which includes not only the earthy marl, which is commonly of a yellowish grey colour, composed of more or less cohesive dusty particles, soiling a little the finger, and rather rough to the touch: and,

Stone Marl, or indurated marl, is usually of a smoky grey, or bluish colour; or sometimes of an ochre yellow, or brownish red. It has a slaty texture; it readily disentegrates by exposure to the air or weather, and frequently contains shells. Shell marl is called either the earthy or the indurated, abounding with shells.

All marls are useful in agriculture, only in proportion to the quantity of calcareous earth they contain: unless they contain more than 30 per cent. of lime they are of no value to the farmer.

From what has been stated already, the analysis of marls becomes obvious. Of all the modes of trials the one best suited to the unlearned farmer is to observe how much carbonic acid the marl gives out, and this he may ascertain by dissolving a little of it in dilute muriatic acid, and observing what portion of its weight it loses by the escape of the carbonic

acid. Thus, if an ounce of marl loses 40 grains, he may conclude that the ounce contained only 100 grains of calcareous earth, and that it would be his interest to pay five times as much for a load of lime as he must pay for a load of marl at the same distance.

Process I.—To find the composition of marl, pour a few ounces of dilute muriatic acid into a flask, place it into a scale and let it be ballanced.

II.—Then reduce a few ounces of dry marl to powder, and let it be carefully and gradually put into the flask, until after repeated additions no further effervescence ensues.

III.—Let the remainder of the powdered marl be weighed, by which means the quantity projected will be known.

IV.—Let the ballance be then restored. The difference of weight between the quantity projected, and that requisite to restore the equilibrium will show the weight of the carbonic acid gas lost during effervescence.

If the loss amount to 13 per cent. of the quantity of marl projected, or from 13 to 33 grains per cent. the marl analysed is calcareous marl, that is to say, marl rich in calcareous earth.

Marls in which clay abounds, (clayey or argil-

laceous marls,) seldom lose more than 8 or 10 per cent of their weight by this treatment. The presence of argillaceous earths in marls may likewise be judged by drying it, after being washed well, when being kneaded together, dried and burnt, it will harden and form a brick.

Sandy marls usually lose the same quantity of carbonic acid, and frequently still less.

ANALYSIS OF CALCAREOUS STONES WHICH ARE NOT SOLUBLE IN DILUTE NITRIC OR MURIATIC ACID, OR AT LEAST VERY DIFFICULT, AND WHICH DO NOT EFFERVESCE WITH THESE AGENTS.

GENUS II.—*Analysis of Sulphate of Lime.*

Process I.—Let one part of the mineral, finely powdered, be boiled with 4 or 5 times its weight of corbonate of potash, in a sufficient quantity of water, for at least 2 or 3 hours, renewing the fluid as it evaporates, and collect the insoluble residue.

II.—Transfer the insoluble part into a flask, containing diluted nitric acid; effect a solution, if possible; examine the solution for barytes and strontia, (see analysis of barytic stones) and

separate the earth which it may contain, according to the rules laid down already.

GENUS III.—*Analysis of Fluates of Lime.*

The stones belonging to this genus are composed of lime united to fluoric acid; they are both amorphous and crystallised; they decrepitate, and become phosphorescent when exposed to heat, except the colourless ones, which become electric by friction. They are generally crystallised in cubes. They are more or less transparent, and exhibit various colours, particularly violet, purple, red, yellow, and white. They melt before the blow-pipe into a transparent glass. They take a fine polish, and are worked into vases, vessels, and a variety of ornaments. The stones belonging to this genus are all decomposable by sulphuric acid, the fluoric acid becomes expelled, and may be known by the property of dissolving glass; for that purpose let a quantity of the powder be moistened with sulphuric acid in a leaden or pewter vessel; heat the mixture over a lamp, and expose to the acid vapours, a plate of glass, which will soon become corroded. Their phosphorescent property may be evinced, by throwing the stone, reduced to a coarse pow-

der, upon a shovel, or plate of metal, heated so as not to be visible in the day. They may be examined in the following manner:

Process I.—Take one part of the stone finely pulverised, put it into a leaden retort, pour over it four parts of sulphuric acid, join to the retort a leaden receiver, containing two parts of water, lute the junctures of the vessel, and distil till no more vapours come over. The water in the receiver will be converted into fluoric acid.

II.—Wash the mass contained in the retort in a small portion of water, boil the insoluble residue with carbonate of potash, as directed, page 394; re-disssolve it in nitric or muriatic acid, and examine it as stated, page 395.

III.—Decompose the fluid from which the insoluble part of process I. was separated by carbonate of potash, and assay it for lime, magnesia, and alumine, as stated before 386, &c.

Genus iv.—*Analysis of Phosphates of Lime.*

Process I.—Digest a determined quantity of the mineral in 5 times its quantity of muriatic acid, and repeat this operation till the fluid acts no more upon the residue, decant the liquid, dilute it with water, and filter it.

II.—Mingle the muriatic solution with liquid ammonia, collect the precipitate, wash, dry, and heat it.

III.—Re-dissolve this precipitate in a sufficient quantity of nitric acid, and precipitate by the addition of sulphuric acid. The whole must then be filtered, and the insoluble part washed with as little water as possible.

IV.—The filtered fluid must now be evaporated to the consistence of a syrup. If the stone consists of phosphate of lime, the fluid thus obtained will be phosphoric acid. That it is phosphoric acid may be proved by its copious precipitation of lime water, by its giving white precipitates with the solutions of sulphate of iron and nitrate of mercury, and its incapability of precipitating nitrate and muriate of barytes.

Genus v.—*Analysis of Borate of Lime.*

To this genus belongs only a single species, namely, the mineral called Dalholite.

Process I.—Digest one part of the mineral repeatedly in nitric acid by heat, till a new ad-

dition of acid does not produce any further action on the residue.

II.—Decompose the nitric solution by carbonate of soda, and separate the precipitate by filtration.

III.—Mingle the solution with sulphuric acid, till the taste of the latter predominates: evaporate the fluid to dryness.

IV.—Transfer the dry mass into alcohol, digest it by heat, and then evaporate the alcoholic solution. If now a salt is left behind, which reddens tincture of litmus, and which tinges the flame of burning alcohol green, the substance examined was borate of lime, or boracite. If the alcoholic solution is evaporated the boracic acid will be obtained in a pure state. The remainder of the dry mass may be analysed by the rules stated before.

The analysis of arseniate of lime has been stated already.

TABULAR ARRANGEMENT

OF

CALCAREOUS STONES,

ACCORDING TO THEIR CHEMICAL COMPOSITION, AND EXTERNAL CHARACTERS.

GENUS I.—*Carbonates of Lime.*

Compact, or common lime stone
Foliated lime stone
Calcareous spar
Magnesian lime stone
Fibrous lime stone, or sattin spar
Granular lime stone, including all the varieties of marble
Siliceous lime stone
Testaceous carbonate of lime, or schaalstone
Compact fetid, or bituminous lime stone, swine stone

Ochreaceous foetid lime stone
Pisolite, or pea stone
Oolite, or roe stone, ketton stone, meconite, or ammite
Botroydal carbonate of lime, or calcareous stalactite
Coralliform lime stone, or flos ferri
Margaritiform lime stone, or pearl spar
Madreporite
Dolomite
Argentine, or slate spar, schifer spar
Magnesian argentine, silvery chalk, or schaum earth
Brown spar, sidero calcite, ferriferous carbonate of lime, ferrugenous pearl spar
Arragonite
Chalk
Rock, or mountain milk
Calctuff
Calcareous marls

GENUS II.—*Sulphates of Lime.*

Fibrous sulphate of lime, or fibrous gypsum
Granular foliated gypsum, or alabaster
Earthy gypsum, or gyps earth
Granular anhydrous gypsum, or bardiglio marbl

Compact anhydrous gypsum, muriacite, cube or rhomb spar

Genus III.—*Fluates of Lime.*

Earthy fluate of lime, blue John of the Derbyshire miners, or Derbyshire spar
Compact fluate of lime
Argillaceous fluate of lime, or chlorophane

Genus IV.—*Phosphates of Lime.*

Native phosphate of lime, phospholite, or apatite
Earthy phosphate or moroxite of lime
Conchoidal phosphate of lime, asparagus stone, or chrysolite of Rome de Lisle
Foliated phosphate of lime
Siliceous phosphate of lime

Genus V.—*Borate of Lime.*

Native borate of lime, or datholite

Genus VI.—*Arseniate of Lime.*

Native arseniate of lime, or pharmacolite.

ORDER III.

ARGILLACEOUS STONES.

Division of Argillaceous Stones.

Under this head mineralogists comprehend not only those earths and stones in which alumine forms the most predominant part, but also those to which this earth gives a peculiar character. Hence all the clays are arranged among the argillaceous minerals, because the characters of alumine are particularly conspicuous in them, although in the greatest number of them this earth never forms the most predominant part. It is remarkable that alumine has the peculiar property of imparting characteristic properties to a very large proportion of other earths, when in combination with them. Is found nearly pure in the hardest gems only.

The oriental ruby, the oriental topaz, the oriental emerald, the oriental saphir, &c. all belong to this class; minerals in which the

existence of alumine was for ages unsuspected, and where it exhibits properties widely different from those which it exhibits in clay; or in the minerals commonly called argillaceous.

The earths and stones in which alumine enters as a leading constituent part, may be divided in the following manner:

GENUS I.—*Argillaceous Stones composed of Alumine united to a small portion of silex and lime.*

GENUS II.—*Argillaceous Stones composed of alumine, united to a portion of silex, lime, and magnesia.*

GENUS III.—*Argillaceous Stones composed of alumine and a portion of silex and barytes.*

CHARACTERS OF ARGILLACEOUS STONES.

Although from what has been premised, page 402, it becomes obvious that no general characters can be given, that might serve for discriminating argillaceous stones, without error, from other mineral compounds: the greatest number

of those earthy combinations of which alumine constitutes a leading ingredient, may, however, be said to possess the following habitudes, namely: they are entirely destitute of transparency, devoid of vitreous lustre, and have an acid dry appearance, or exhibit, when broken, an earthy fracture. The greatest number of them are acted on, or are more or less dissolved, by acids, particularly when assisted by heat. They may be scratched with a knife, and emit a peculiar odour when breathed on, a few excepted, known by the name of a clayey or earthy smell.

The greatest number feel rather soft to the touch, and suffer impressions by the finger nails. They become very hard, and less in bulk, after having been exposed to heat. They readily absorb water, and retain it obstinately. They also form with water, when reduced to a fine powder, a kneadable tenaceous and ductile mass. They fuse with lime, but not with alcalies; at least they require a very large portion of alcali to render the combination perfect.

If a mineral be found, whose properties coincides, or nearly so, with the description here given, we may ascertain whether it propertly belongs to the argillaceous stones, thus:

ANALYSIS OF ARGILLACEOUS STONES.

If the mineral is not very hard, or exists in such a state of aggregation, as permits it to be readily converted into a fine powder, the following mode of analysis may be pursued:

Process I.—Expose a weighed quantity of the stone, broken into small pieces, to a red, or better to a white heat in an earthen ware retort, and collect the moisture, if any, in the usual manner, by means of a receiver adapted to the retort.

II.—Take another portion of the stone, finely pulverised, boil it to dryness with 4 parts of its weight of concentrated sulphuric acid diluted with 1 of water, and a small portion of potash, or acetite of potash.

III.—Transfer the mass into water, boil it for a few minutes, separate the insoluble residue, dry it, and then boil it again with sulphuric acid and potash, and proceed as before for several times successively, until no further action takes place. The silex and lime will thus be left behind. These earths may be examined with regard to their purity, in the manner stated already.—See analysis of Siliceous and Calcareous Stones.

IV.—To ascertain the quantity of alumine, which by this means will be converted into sulphate of alumine and potash, concentrate the solution by evaporation, and decompose it at a boiling heat, by a solution of sub-carbonate of potash. This precipitate, after having been exposed to heat, to free it from carbonic acid, gives the quantity of alumine that was present in the stone, though not in a state of perfect purity. For be it understood that from whatever acid solution alumine is separated by virtue of an alcali, it always retains a minute portion of the substance employed to precipitate it.*

V.—To ascertain the true quantity of this earth, which is present in the mineral, the precipitate must be re-dissolved in acetous acid, again precipitated by liquid ammonia perfectly free from carbonic acid, dried, and ignited.

During the evaporation of the solution of alumine, from which the silex has been separated, as stated before, process IV. portions of the latter earth become separated even to the last; these should be collected, and added to that obtained already, as will be shown presently.—See analysis of adamantine spar, or corundum, &c.

* See the Author's System of Chemistry, 2nd edition, vol. I: p. 221.

VI.—The oxid of iron which is usually present may be separated from the silex by heating it in a crucible with a little wax, which renders the iron soluble in dilute muriatic or sulphuric acid, when applied, and the silex is left behind pure. The oxid of iron may then be precipitated from the acid solution by liquid ammonia.—See analysis of iron ores.

Example 1.—*Analysis of Native Alumine.*

Process I.—One hundred grains of native alumine,* from Schemnitz, were exposed to a strong red heat for one hour in a covered crucible. After cooling, they had lost 41 grains, which was water. No alteration was effected in the appearance of the earth, during this process, except that the pieces of the mineral were become a little rifty, and considerably diminished in size.

II.—Another hundred grains of the same earth were gradually conveyed into sulphuric acid a little diluted. They dissolved in this fluid without effervescence. The sulphuric solution was perfectly colourless; but on being

* Klaproth's Analytical Essays, vol. I. p. 221.

evaporated it formed a clear transparent coagulated mass, the surface of which, after a few days, became covered with a number of solitary pyramidal crystals.

III.—The mass was next drenched and digested with an abundance of water: the siliceous earth thus separated, weighed 14 grains after being ignited.

IV.—The solution, freed from silex was combined with the requisite portion of pot-ash, and evaporated; it afforded pure alum; from which the alumine was afterwards precipitated by subcarbonate of pot-ash, and purified in the manner just mentioned; namely, by acetous acid.

Hence the constituent parts of the so-called native alumine, are, according to Klaproth,

Alumine	45
Silex	14
Water	41
	100

Example 2.—*Analysis of Wavellite, or Hydragellite.*

The analysis of this mineral, which consists

almost wholly of alumine and water, was effected by Mr. Davy in the following manner.*

Process I.—Eighty grains of the mineral were introduced into a small glass tube having a bulb of sufficient capacity. To the end of this tube a small glass globe, attached to another tube, communicating with a pneumatic mercurial apparatus, was joined by fusion, by means of the blow-pipe. The bulb of the tube was exposed to the heat of an Argand lamp; and the globe was preserved cool by being placed in a vessel of cold water. In consequence of this arrangement, the fluid disengaged by the heat became condensed, and no elastic matter could be lost. The process was continued for half an hour, when the glass tube was quite red. A very minute portion only of permanently elastic fluid passed into the pneumatic apparatus, and when examined, it proved to be common air. The quantity of clear fluid collected, when poured into another vessel, weighed 19 grains, but when the interior of the apparatus had been carefully wiped and dried the whole loss indi-

* Philosoph. Trans. 1805, and Nicholson's Journal, 1805, vol. XII. p. 153.

cated was 21 grains. The 19 grains of fluid had a faint smell, similar to that of burning peat; it was transparent, and tasted like distilled water: it slightly reddened litmus paper: it produced no cloudiness in solutions of muriate of barytes, of acetite of lead, of nitrate of silver, or of sulphate of iron.

II.—The 59 grains of solid matter were dissolved in dilute sulphuric acid, which left no residuum; and the solution was mixed with potash, in sufficient quantity to cause the alumine at first precipitated again to dissolve. What remained undissolved by potash, after being collected and properly washed, was heated strongly and weighed; its quantity was a grain and a quarter. It was white, caustic to the taste, and had all the properties of lime.

III.—The solution was mixed with nitric acid till it became sour. Carbonate of ammonia was then poured into it till the effect of decomposition ceased. The whole thrown into a filtrating apparatus left solid matter, which when carefully washed and dried at the heat of ignition, weighed 56 grains. They were pure alumine: hence the general results of the experiments, when calculated upon, indicated for 100 parts of the mineral:

Alumine	70 grs.
Lime	1.4
Water	26.2
Loss...............	2.4
	100

N. B. The loss Mr. Davy is inclined to attribute to some fluid remaining in the stone after the process of distillation; for he learnt from several experiments, that a red heat is not sufficient to expel all the matter capable of being volatilized, and that the full effect can only be produced by a strong white heat.

Fifty grains of a very transparent part of the fossil, by being exposed in a red heat for fifteen minutes, lost 13 grains; but when they were heated to whiteness, the deficiency amounted to 15 grains, and the case was similar in other trials.

Example 3.—*Analysis of Adamantine Spar, or Corundum, from Bengal.*

Process I.—One hundred grains of the stone triturated with water in a flint mortar, were

found, after drying and ignition, to have increased 11 grains in weight,* which was owing to particles of flint abraded from the mortar.

II.—Upon these 100 grains, four ounces of a solution of potash, containing one half its weight of alcali, were affused in a silver crucible; and the mixture evaporated to dryness. The mass being then ignited for three hours, was again softened with water, and diffused through that fluid and filtered. The residue weighed 47 grains.

III.—The obtained fluid, process II. let fall, on being saturated with muriatic acid, a copious white precipitate, which was immediately redissolved by a slight excess of acid.

IV.—The above obtained 47 grains, process II. completely dissolved in muriatic acid. When this solution was mixed with liquid ammonia, it afforded a slimy and very puffy precipitate. Carbonate of ammonia was then added to the liquor, which had been immediately separated from this precipitate by filtering, but no farther precipitation ensued.

V.—The obtained precipitate was transferred into a solution of potash and digested for some

* Klaproth's Analytical Essays, vol. I. p. 65.

time. The mixture assumed the appearance of a solution of gum arabic. On adding more potash, the whole formed a limpid fluid, except some few brown flocks, which, after having been dried, weighed $2\frac{1}{4}$ grains.

VI.—Muriatic acid being affused upon this flocculent precipitate, a small portion of silex again separated, and liquid ammonia precipitated from the clear solution oxid of iron, weighing, after ignition, $1\frac{1}{4}$ grain.

VII.—From the alcaline solution, V. muriatic acid threw down a precipitate, which was entirely re-dissolved by a small excess of that fluid.

VIII.—Both the solutions, process VII. and III. were next mixt and precipitated by carbonate of potash at a boiling heat, and the dried precipitate was again dissolved in dilute sulphuric acid. When this solution, after the addition of a sufficient quantity of potash, had been evaporated to the point of crystallization, it readily afforded clear and regular crystals of alum.

IX.—The remaining part of the solution in sulphuric acid, process VIII. thickened spontaneously to a clear jelly, on subsequent evaporation. This gelatinous matter, being digested

with an abundant quantity of water, and repeatedly agitated, again liquefied by degrees. Upon this, some silex subsided; which, when separated by means of a filter, and ignited, amounted together with that obtained, process VI. to $15\frac{1}{2}$ grains, after having been boiled and digested in sulphuric acid.

X.—The above solution in sulphuric acid, was then evaporated for further crystallization. It continued to the end to yield successively regularly crystallized sulphate of alumine: but the very last portion was still contaminated with siliceous earth, amounting to 1 grain after ignition.

XI.—All these several portions of alum were dissolved in water, and precipitated in a boiling heat by sub-carbonate of potash: and when the alumine which they afforded had been purified by means of acetic acid, as stated before, they gave $82\frac{1}{2}$ grains of pure alumine.

Therefore, the products obtained by the decomposition of the adamantine spar from Bengal yielded to Klaproth,

Alumine	process XI.		89,50
Oxid of Iron	VI.		1,25
Silex	IX.	$15\frac{1}{2}$	
	X.	1	
		$16\frac{1}{2}$	
Subtract, process I.		11	
Remain........		$5\frac{1}{2}$	5,50
			96,25
		Loss....	3,75
			100

Example 4.—*Analysis of Chrysoberil.*

Process I.—One hundred grains of chrysoberyl,* previously reduced to a powder, were levigated with water to perfect fineness in a flint mortar. After the powder had become dry, it was subjected to gentle ignition, in order to free it from all moisture. However, its weight was increased 13 grains, by the abraded particles of the mortar and pestle.

* Klaproth, ibid. p. 86.

II.—Upon these 113 grains, introduced into a silver crucible, was poured so much of a solution of potash, that the proportion of alcali which it contained amounted to 800 grains: the mass was evaporated to dryness, and lastly fused for about two hours.

III.—The fused alcaline mass being softened in the crucible with water, the solution was thrown upon a filter. When the fluid had passed through the paper, there remained a loose, light-grey powder, which being washed and dried, weighed $66\frac{1}{2}$ grains.

IV.—The alcaline fluid that had been separated from this powder, together with the water employed for washing the residue in the last process, was first evaporated, to lessen its bulk, and then saturated with muriatic acid. An abundant white precipitate fell down, which was instantly re-dissolved by a small excess of acid. Carbonate of potash being added, again occasioned a precipitate, which being collected, washed, and dried, was porous and white as snow: it weighed $138\frac{1}{2}$ grains.

V.—The light grey pulverulent residue, of process III. amounting to $66\frac{1}{2}$ grains, on being digested in muriatic acid, left again a residue; which being washed, dried, and ignited, weighed

$24\frac{1}{2}$ grains, and was found, upon farther examination, to be another portion of pure silex.

VI.—The muriatic solution obtained, process V. which was separated from the silex, was next decomposed at a boiling heat, by liquid ammonia, which occasioned a yellowish precipitate. It was washed; and, while yet moist, boiled with a solution of potash; in which it entirely dissolved, some few brown particles excepted; which was oxid of iron, weighing, after ignition, $1\frac{1}{2}$ grain.

VII.—The alcaline solution, process VI. being saturated with muriatic acid, yielded a white precipitate, which, by a slight excess of acid, again formed a clear solution. The precipitate was a second time precipitated, by boiling it with carbonate of potash. Its weight amounted, after desiccation, 29 grains.

VIII.—These last 29 grains, together with the preceding $138\frac{1}{2}$ grains of the product, process IV. to which was also added the two grains which were collected from the washings by evaporation, were digested with dilute sulphuric acid. The whole was dissolved, excepting a portion of silex, which weighed 4 grains.

IX.—When this solution was a little evaporated at a low temperature, tender, spicular, or

spear shaped crystals, gradually separated; which were collected. They presented all the marks of selenite, or sulphate of lime; and, on decomposition by a solution of carbonate of potash, in boiling heat, they afforded 11 grains of carbonate of lime = to 6 of lime. This calcareous earth of the chrysoberyl was, doubtless, before contained in the precipitate of process IV. and previous to its falling down, it was held in solution merely by the water, as it was then in the state of lime free from carbonic acid.

X.—This sulphuric solution was now combined with the proportion of carbonate of potash requisite to the formation of alum, which yielded, by degrees, regular crystals. Towards the end, however, a slight portion of silex appeared, which being ignited, weighed $2\frac{1}{2}$ grains. The total weight of the sulphate of alumine obtained amounted to 604 grains.

This alum was re-dissolved in boiling water, and decomposed by carbonate of potash, at the heat of ebullition. After the precipitated alumine had been washed, dried, and gently ignited, it was digested with distilled vinegar; the solution being neutralized by liquid ammonia, the alumine was again precipitated by this treatment, which, after being again washed,

dried, and heated to redness, proved to be perfectly pure. It weighed 71½ grains.

We may, therefore, infer, that the constituent parts of the chrysoberyl, exhibited by this analysis, consist in the hundred, of

Alumine	process X.		71,5
Lime	VIII.		6
Oxid of Iron	VI.		1,5
Silex	V.	24½	
	VIII.	4	
	X.	2½	
		31	
	Subtract, process I.	13	
	Remain..........		18
			97
		Loss	3
			100

Example 5.—*Analysis of Cimolite.*

Process I.—One hundred grains of cimolite, in entire pieces, were exposed, for half an hour,

to the heat of a furnace, in a covered crucible. After cooling, it was found split into slaty fragments, of uneven surfaces. This process was accompanied, at the commencement of ignition, with a crackling noise. The cimolite acquired, at first, a brownish grey colour, which again disappeared. It lost 24 grains in weight during this operation.

II.—Two hundred grains of finely pulverised cimolite, being next mixed, and ignited with thrice their quantity of potash, in the usual manner, afforded, after cooling, a blueish, or greenish-white mass, which, being softened with water, left an insoluble part, which was separated by the filter.

III.—The alcaline fluid, which was colourless, was mingled with sulphuric acid in excess. The siliceous earth separated in the usual manner weighed 44 grains, when perfectly dried.

IV.—The residue of process I. which was not taken up by the alcali in that process, weighed 220 grains. It was dissolved by degrees, by being digested in sulphuric acid; but no compleat solution was effected. It left behind five grains of silex.

V.—Both the sulphuric solutions, namely, process III. and IV: were added together, and

partly evaporated; after which, crystals of alum appeared, on suffering the liquor to cool. The remainder of the fluid, on being farther evaporated, became gelatinous. When mixed with water, digested, and filtered, there again separated a portion of silex, in the form of pellucid vitreous grains, the weight of which was 64 grains.

VI.—The remaining fluid was mixt with prussiate of potash, which produced a deep blue precipitate; by the quantity of which the proportion of oxid of iron was determined in the usual manner at $2\frac{1}{2}$ grains.

VII.—The iron being separated, a small quantity of potash was added to that part of the sulphuric solution which yet remained. By this treatment, and subsequent evaporations, crystals of alum were obtained, in succession, to the end. But, at the same time, there still separated, from time to time, some siliceous earth, amounting to 13 grains.

VIII.—The whole of the alum produced was, lastly, re-dissolved in water, and the alumine separated by carbonate of potash. This alumine being purified and ignited, amounted to 46 grains.

Therefore, the above 200 grains of cimolite yielded:

Silex, process	III. 44 IV. 5 V. 64 VII. 13		126 grains.
Alumine	VIII.		46
Oxid of Iron	VI.		$2\frac{1}{2}$
Loss by ignition	I.		24
			$198\frac{1}{2}$ grains.

Whence, one hundred parts of cimolite contain:

Silex	63
Alumine	23
Oxid of Iron	1,25
Water	12
	99.25

From what has been so far stated, the analysis of argillaceous earths and stones will become obvious. The extreme hardness of some of these compounds belonging to this class, particularly those usually called gems,

render the analysis of them difficult. Mr. Chenevix, however, has succeeded, by help of borax, in decomposing them. His method is as follows:

Process I.—Take one part of the stone, levigated as fine as possible, mix it with 3 or 4 times its weight of glass of borax, (borax compleatly freed from water by fusion) and expose the mixture to a violent heat, in a platina crucible, for at least 2 or 3 hours.

II.—To detach the mass from the vessel to which it adheres very firmly, digest the whole for some hours in muriatic acid, to effect a solution.

III.—Into the obtained fluid let fall sub-carbonate of ammonia till no further cloudiness ensues, and collect the precipitate on the filter. All the earths which were present will then be thrown down.

IV.—Re-dissolve the obtained precipitate in muriatic acid, the borax being thus got rid of, the analysis may be finished in the manner already stated.

Remark.—10 Mr. Chenevix separated the alumine in his analysis of the corundum, from its alcaline solution in potash, by muriate of am-

monia; the potash, in this case, joins to the muriatic acid of the muriate of ammonia, and the ammonia set free, determines the precipitation of the alumine, which, when washed, is is perfectly pure.* We owe to Mr. Chenevix some very singular observations, with regard to the affinities of alumine with other earths, which are of the utmost importance to the practical analyst, as it regards the truth of all analyses in which this earth enters, namely, it is well known that magnesia cannot be completely separated from its acid solutions by ammonia, for part of the magnesia combines with ammonia, and forms with it and the acid a triple salt; but the case is otherwise, when magnesia is associated with alumine in the same solution; in that case the ammonia first separates the greatest portion of alumine, together with a *larger* quantity of magnesia than would have been precipitated by the ammonia *only*, or *without* the presence of alumine; and it is only after the ammonia has thus acted, that a farther addition of it forms the ammoniacal triple salt of magnesia above-mentioned. The same case takes place when a carbonated alcali, fully satu-

* Philoseph. Trans. 1802, p. 33.

rated with carbonic acid, is employed. For, if this alcali be added to a solution containing magnesia, no precipitate takes place; or if any, as is the case, if the alcali be not fully saturated with carbonic acid, the carbonate of magnesia formed is immediately re-dissolved; but if alumine be present, the alcali throws down both of the earths in combination: hence the power of the resolubility is lost, except that dose of the alumine which exceeds the saturating affinity of magnesia. For these singular and important facts we are indebted to Mr. Chenevix, who first published them in the 28th volume of the An. Chem. p. 203.—See page 437 of this work.

Lime, likewise, has a powerful affinity for alumine; for when these two earths are present in a solution, ammonia, when added to it, will separate a portion of lime, which is not the case when lime alone exists in the fluid; hence the mode of separating lime from the other earths, by means of ammonia, with a view of leaving the lime in solution, as often directed, is certainly objectionable, for a portion of the lime falls down, together with the other earth, and the quantity of it will therefore be less than it ought to be. To remedy this defect it is ad-

visable to throw down the whole contents of the solution by a carbonated alcali, to convert all the substances into carbonates. The subsequent application of potash or soda will then take up the alumine, and not touch the lime, which is now in a carbonated state.

Magnesia and alumine may also be separated by succinate of soda, which precipitates the latter earth only.

With regard to the oxids of iron, which are usually present in all argillaceous fossils, the separation of it is by no means troublesome. The alcali employed in taking up the alumine does not touch the oxid of iron, if in a state of red oxid, to which it may be brought by exposure to heat, or nitric acid; if a portion should, however, adhere to the alumine, it may be removed by dissolving the alumine in muriatic or nitric acid, and then separating the iron by prussiate of potash.

Mr. Chenevix has suggested several modes of performing the very difficult operation of separating magnesia from alumine. The first is founded on the insolubility of malate of lime, and the production of a very deliquescent salt: namely, malate of magnesia. If this acid therefore be added to a solution containing both these earths,

the malate of magnesia may be removed by the operation called deliquation, or by ablution with alcohol, which does not touch the malate of alumine, but very readily dissolves the malate of magnesia. The second mode consists in the application of water impregnated with sulphuretted hydrogen gas, which, with magnesia, forms a salt readily soluble in water, without acting on the alumine. And a third mode is by the application of Prussic acid, which also forms, with magnesia, a readily souble, and with alumine, a very insoluble compound. It is not necessary that these re-agents should be added in a naked state, hydo-sulphuret of potash, or an alcaline prussiate, answer equally well. The malic acid appears to deserve the preference to the two others; for, if iron is present, the malate of iron is very soluble, but the prussiate and hydro-sulphuret of iron are insoluble, or nearly so; hence the malic acid yield the alumine in a pure state, whereas by the application of the other two, a subsequent process is requisite to get rid of this metal.

Klaproth separates these earths when no others are present, by dissolving them in sulphuric acid, thus converting the alumine into sulphate of alumine, and evaporating the whole

to dryness, and strongly igniting it for half an hour. If now water be added, the sulphate of magnesia will only be soluble, and the sulphate of alumine only on the addition of a portion of sulphuric acid and potash. In this case it is however necessary that the sulphuric acid should be perfectly pure. The sulphuric acid of commerce cannot be employed, for it always contains a small portion of sulphate of potash, which would at once produce alum and not sulphate of alumine.

We shall treat again on the modes of separating these earths under the article, analysis of mineral waters.

TABULAR ARRANGEMENT

OF

ARGILLACEOUS STONES,

ACCORDING TO THEIR CHEMICAL COMPOSITION AND EXTERNAL CHARACTERS.

Argillaceous Stones chiefly composed of Alumine almost pure, or united to a portion of Silex and Lime.

Telesia, saphir, or perfect corundum, oriental ruby of the jewellers
White telesia, oriental or water saphir, white corundum
Yellow telesia, or oriental topaz
Blue telesia, or oriental saphir
Violet telesia, or oriental amethyst
Green telesia, or oriental emerald
Imperfect corundum, or adamantine spar
Scotch corundum* or andalusite.

* Sowerby's Mineralogy, pl. 69.

Spinel, or true ruby, balass ruby, or rose-red shorl
Violet red spinel
Yellow red spinel
Orange red spinel, or rubicelli
Emery
Wavellite, or hydragillite
Brazilian topaz
White hyacinth, sommet, or nepheline
Chrysoberil, or Cimophane
Dypyre, leucolite, or shorlite
Sommite, or white hyacinth
Cimolite
Automalite
Turmaline, or shorl
Yellow, or Brazilian shorl
Green shorl
Saphyrine shorl
Siliceous shorl
Clay stone
Pure clay, or Koolin
Petuntse
Porcellain clay
Pipe clay
Variegated clay
Brick clay
Loam

Yellow ochre
Lythomarge
Fuller's earth
Bole
Tripoli
Argillaceous marl

Argillaceous Stones composed of Alumine, with a portion of Silex, Lime, and Magnesia.

Ceilanite, or Pleonaste
Ceyanite, Sappare, or Disthene
Clinkstone
Mica
Micarel
Wacke, or grey wacke
Grey wacke slate
Argillaceous shistus, or argillite
Alum slate
Novaculite and honestone
Drawing slate
Adhesive slate
Chlorite
Chlorite slate
Foliated Cholorite
Diaspore

Phrenite
Kaupolite, or foliated phrenite

Argillaceous Stones containing a portion of Silex and Barytes.

Staurolite, stauro-baryte, ercticite, andreolite, or grenatite

ORDER IV.

MAGNESIAN STONES.

Division of Magnesian Stones.

To this order of earths and stones belong not only those which are chiefly composed of magnesia, but those minerals also in which, though in smaller proportion, there exists the totallity of the characters, which may be said to be characteristic of the genus. Magnesian stones sometimes consist of two earths, sometimes of three. They may be divided in the following manner:

GENUS I.—*Magnesian Stones chiefly composed of Magnesia united to Boracic Acid, or Borates of Magnesia.*

GENUS II.—*Magnesian Stones chiefly composed of Magnesia, with a portion of Silex and Lime.*

Genus iii.—*Magnesian Stones chiefly composed of Magnesia, with a portion of Silex and Alumine.*

CHARACTERS OF MAGNESIAN STONES.

Most of the stones of this order have a greenish colour, more or less deep, but they possess more or less a glittering or shining surface, seldom, if at all, an earthy appearance; they do not adhere to the tongue; they very seldom exhibit a regular crystalline form; they do not, or few of them only, effervesce with acids, but they are soluble in boiling sulphuric acid. Their texture is generally scaley or lamellar: seldom they have an even texture. They are only semi-transparent, but oftener inclined to opake.—Their substances are more or less smooth; hence they feel soft, or rather soapy to the touch: they do not stain the fingers, nor do they soften in water like many of the argillaceous stones. They discover no clayey smell when breathed upon: they may be cut with a knife, or with a machine, or turned on the lathe: they do not contract or harden after

having been exposed to heat, and are infusible with potash.

ANALYSIS OF MAGNESIAN STONES.

The native combinations of magnesian stones, as stated already, consist chiefly of two or three earths, namely, magnesia, alumine, and lime, and in general some metallic oxid; the analysis of them must become easy, on considering what has been said in the preceding pages. The separation of magnesia from alumine, to which it has a very marked affinity, is attended with some peculiar difficulties. They certainly depend on the strong affinity which exists between these earths, which modifies and alters the usual modes in which they are acted on by the different chemical agents, when in a detached state. This affinity was first pointed out by Chenevix.* Namely: when magnesia is dissolved by an acid, it is only partially precipitated by liquid ammonia, and if there be an excess of acid, the earth is not precipitated at all; for ammonia has a tendency to form with

* An. de Chem. VIII. p. 168.

them a terrary compound. Hence when liquid ámmonia is added to a solution of a magnesian salt, part of the magnesia is precipitated, but another portion remains in combination with the acid, and the ammonia, forming a soluble salt. These ammoniacal magnesian salts were first noticed by Bergman,* and more fully examined by Fourcroy† and Chenevix. But the case is otherwise when alumine is present. In that case the decomposition is compleat, for the whole of the magnesia is precipitated together with the alumine, see p. 424. Thus Chenevix found that on adding an excess of ammonia to a solution of muriate of magnesia, mixed with a large proportion of muriate of alumine, nothing remained in solution but muriate of ammonia. Hence, also, when a solution of carbonate (not sub-carbonate) of potash, is poured into a solution of Epsom salt, or sulphate of magnesia, no precipitate ensues, the mixture remains perfectly transparent, because the carbonic acid evolved is sufficient to hold the whole in solution; but, if sub-carbonate of potash is emplyed, an abundant precipitate is produced, and, if alumine be present, the carbonate of potash will throw

* Chemical Essays. † Annales de Chemie, tom. IV.

down a precipitate, consisting of both the earths. When this precipitate is boiled in a solution of potash, only a very small portion of alumine is dissolved, the greater part being retained by its affinity for magnesia. By dissolving the residuum in muriatic acid, and then adding to the solution carbonate of potash, a portion of magnesia is retained in solution. Potash boiled on the residue dissolves a fresh dose of alumine, and by repeating these operations alternately, the two earths may be separated from each other. Thus we see that the action of magnesia on alumine is the reverse of the action of alumine on lime.

The last promotes the solution of the lime, whereas the first prevents the solution of the alumine.

This being premised, we shall state the general modes employed in the analysis of magnesian stones, together with a few examples given by Klaproth.

Process I.—Let one part of the stone be ground to a fine powder, pour over it two or three parts of sulphuric acid, diluted with half a part of water, boil the mixture to dryness, and heat it till no more white fumes rise.

II.—Transfer the dry mass into twice its weight of water, digest it in the cold for some hours, and then filter it. It yields, on evaporation, a crystalline salt of a bitter taste. Dissolve it in water.

III.—Decompose this solution by sub-carbonate of potash, dry the precipitate, and heat it; which, if the stone contained magnesia only, will be the earth called magnesia, which may be distinguished from alumine by being insoluble in caustic potash, and forming bitter salts with sulphuric acid.

Example 1.—*Analysis of Miemite.*

Process I.—One hundred grains of Miemite were ground to a fine powder, and covered with nitric acid. The action was slow, and attended with a weak effervescence; but on the application of heat, the solution was rapidly accomplished, with a very violent effervescence. Only a few brown flocks remained, which dissolved by the admixture of a few drops of muriatic acid.

II.—The obtained solution was mingled with liquid ammonia in excess, which yielded a brown precipitate. This being washed, was

boiled while yet moist in a solution of soda, to free it from alumine; but nothing was found soluble in it. The same precipitate was therefore next dissolved in sulphuric acid, the solution evaporated to dryness, and, lastly, ignited for half an hour. This mass being re-dissolved in water, some brown-red flocks remained, which after being again ignited, weighed 2¼ grains, and proved to be oxid of iron, with a slight trace of manganese. As there is no doubt but the iron is contained in the stone in the carbonated state; three grains of carbonate of iron must be accounted for it. The fluid from which this oxid has been separated, on being evaporated, yielded sulphate of magnesia.

III.—That fluid which afforded on the addition of liquid ammonia the before-mentioned brown precipitate, was combined in a boiling heat with carbonate of potash; a white light precipitate fell down, which being washed and mingled with dilute sulphuric acid, produced sulphate of lime. It was carefully collected and decomposed by boiling it with a solution of carbonated soda, as stated before (see analysis of siliceous and calcareous stones.) The carbonate of lime, thus produced, weighed 53 grains, when dried in a warm place.

IV.—What remained of the fluid from which the sulphate of lime had been separated, yielded on farther evaporation, crystals of sulphate of magnesia. This, together with that portion obtained in process II. was decomposed in a boiling heat by carbonated soda. The sub-carbonate of magnesia which was here obtained, being washed and dried in a gentle heat, amounted to 42½ grains.

V.—One hundred grains of the same miemite in entire pieces, were exposed in a covered crucible, to a strong red heat for 30 minutes. They were rendered friable, and had acquired a dark isabella-yellow colour, and lost 52 grains of weight.

Yet, since the whole weight of the carbonic acid contained in the mentioned 53 grains of carbonate of lime, as well as in the 42½ grains of magnesia, and in the 3 grains of oxid of iron, according to the usual proportions, can amount only to 39 grains; it is obvious, says our author, that the surplus of 13 grains lost by the ignition, must be considered as water expelled. Of these, in fact, we again find the greatest part in the carbonate of magnesia. For, the quantity of water with which this earth, while preci-

pitating, combines so intimately, that it parts with it only at a red heat, at which also its carbonic acid is driven out, amounts in 100 parts of carbonate of magnesia to 27; while the carbonic acid contained in it amounts only to 33.

The constituent parts of miemite, therefore, are in the hundred:

Carbonate of Magnesia	42.50
Carbonate of Lime	53.
Carbonate of Iron, with a vestige Manganese	3.
	98.50

Example 2.—*Analysis of the Prismatic Magnesian Spar.*

Process I.—One hundred grains were finely triturated, and introduced into cylindrical glass, which held a quantity of nitric acid sufficient to effect the solution, and was previously put in equilibrium in a scale. The acid acted but feebly, the solution proceeded but slowly, and was accompanied by no great effervescence. After the end of the solution, a loss of 47¼

grains was found, owing to carbonic acid which had escaped.

II.—The solution which was at first yellowish, but colourless when diluted with water, was not disturbed by adding to it a few drops of sulphuric acid; a proof that it contained neither barytic nor strontian earth. It was mixed with as much carbonate of potash as was necessary to neutralize the predominant acid, and then assayed for iron by means of succinate of soda. The precipitated succinate of iron, when ignited, obeyed the magnet. After a few drops of oil had been burnt over it, it presented itself as a black oxid of iron, weighing 2½ grains. But since the iron exists in this fossil in the carbonated state, we must reckon 4 grains for it.

III.—The solution freed from iron, was decomposed with carbonate of potash at a boiling heat. The precipitate obtained, amounted to 96½ grains, when washed and dried.

IV.—This precipitate was saturated with dilute sulphuric acid. By this means sulphate of lime, mixed with sulphate of magnesia, was obtained; the mixture being evaporated to dryness, and elixiviated with cold water, the filtered fluid yielded nothing but crystals of sulphate of magnesia. This being re-dis-

solved in water, and decomposed in a heat of ebullition by means of sub-carbonate of potash, afforded 36½ grains of dried carbonate of magnesia; which deducted from the preceding 96½ grains, reduces the amount of the carbonate of lime to 60 grains.

Hence one hundred grains of the prismatic magnesian spar yielded,

Carbonate of Magnesia	36.50
Carbonate of Lime..........	60.
Carbonate of Iron...........	4.
	100.50

However, since the quantity of carbonic acid, combined with those proportions of the three constituent parts here stated, amounts only to 40½ grains, and in particular the

36.½	grains of	carbonate of magnesia	to	12 grs.
60.	do.	carbonate of lime	—	27
4.	do.	carbonate of iron	—	1.50
				40.50

whereas the native fossil itself contains 47¼ grains, process I. hence 6¾ grains more: some

correction in the above statement is necessary, and this relative to the proportion of the carbonic acid combined with the magnesia.

"The carbonate of magnesia, prepared in the usual way by precipitation from acids, contains upon average 40 per cent. of magnesia, 27 water, 33 carbonic acid. But magnesia, like potash and soda, is capable of appropriating to itself a greater proportion of carbonic acid. For, if carbonate of magnesia, when recently prepared and still moist, be diffused in water, poured into a capacious bottle filled with carbonic acid gas and agitated, the volume of the gas will be found to decrease in a much greater proportion, than can be absorbed by the quantity of water employed to drench the earth. Thus soda, perfectly saturated with carbonic acid, whether by nature or by art, contains less water of crystallization, in proportion as the quantity of carbonic acid combined with it increases. From analogy it was reasonable to conjecture, that the same is the case with magnesia; and this supposition is confirmed by the greater proportion of carbonic acid, discovered in that magnesia, which is a co-constituent part of the fossil here examined, which is a true carbonate, and the artificial, a sub-carbonate."

If now we determine by computation the proportion of the earths and oxid of iron in a state of purity, it amounts in the above-mentioned

$36\frac{1}{2}$ grains of	Magnesia	to	14.50 grs.
60 do.	Carbonate of Lime	—	33
4 do.	Iron	—	2.50
			50.

Adding	
Carbonic acid	47.25
	97.25
Consequently, for the proportion of water remain only	2.75
	100.

According to this calculation, one hundred parts of the prismatic magnesian spar contain,

Magnesia	14.50
Lime	33.
Oxid of Iron	2.25
Carbonic Acid	47.50
Water, and perhaps some loss	2.75
	100.

Example 3.—*Analysis of the Tyrolese Magnesian Spar.*

Process I.—An entire piece, weighing 100 grains, was ignited in a covered crucible for two hours; yet, notwithstanding its sparry texture, it remained entire, without flying to pieces. It was rendered ash-grey, and wholly opake, though preserving some lustre. At the same time its weight was lessened 45 grains.

II.—The action of mineral acids upon this magnesian spar, while in gross framents, was not perceptible; but if pulverized, they attacked and dissolved it gradually, attended with a continued gentle effervescence. With the sulphuric acid, selenite was generated, and the supernatant solution was of a pale-reddish colour. Nitric acid produced a colourless solution, and the muriatic acid a yellow one.

But when pieces of calcined magnesian spar were employed, the solution went on rapidly. And in that case the nitric acid left a metallic residue behind, which was of a brown-red colour.

III.—Three hundred grains of finely powdered magnesian spar, mixed with an equal

quantity of potash, were ignited for two hours n a crucible. The mass returned black out of the fire, except that its middle part was rendered of a dark ash-grey. When triturated, and covered with water, it became light-green. Muriatic acid affused upon it, in sufficient quantity, dissolved the whole, forming a clear yellow tincture.

IV.—This solution was decomposed by carbonate of potash at a boiling heat. Dilute sulphuric acid was next poured upon the precipitate, and the sulphate of lime thus produced, separated from the remaining fluid by the filter.

V.—The solution that remained after the separation of the sulphate of lime, and which contained sulphate of magnesia, was evaporated to perfect dryness, heated red hot for two hours, and lastly re-dissolved in hot water. Upon the filter there remained an oxid of iron, weighing nine grains, wholly obeying the magnet.

VI.—The solution, now freed from the oxid of iron, afforded by subsequent evaporation and crystallization, sulphate of magnesia; which, when decomposed by potash, with the assistance of heat, yielded 133 grains of carbonate of magnesia.

VII.—The sulphate of lime obtained in process IV. being decomposed by boiling it with carbonate of potash, furnished 160 grains of carbonate of lime. To examine whether this still contained any magnesia, it was re-dissolved in nitric acid, and mixed with ammonia, and filtered. The precipitate then formed dissolved in sulphuric acid, and being again precipitated by carbonate of potash, it still yielded three grains of magnesia; which subtracted, leaves 157 grains for the quantity of carbonate of lime.

Consequently, the above 300 grains of the Tyrolese magnesian spar, yielded

Magnesia process	VI.	133	136 grs.
	VII.	3	
Carbonate of lime	VII.		157
Oxid of iron, containing some manganese	V.		9
			302 grs.

As no loss of weight, but rather an excess, appear in the constituent parts, given separately, we may conclude, that those ingredients might, perhaps, have been capable of undergoing a still greater degree of desiccation.

Therefore, a hundred parts of magnesian spar consist of:

Magnesia	45
Carbonate of Lime	52
Oxid of Iron, impregnated with manganese	3
	100

Example 4.—*Analysis of the Silici-Murite, or Meerscham.*

Process I.—One hundred grains of Murite were subjected to a brisk red heat in a crucible, for one hour, they lost 30 grains. But, in other respects, they suffered no alteration in their external appearance. By the result of a previous experiment, hereafter to be mentioned, the loss of weight, which this fossil sustains by ignition, was found to be five parts of water and one of carbonic acid. The above loss of 30 grains is, consequently, divided into 25 grains of water and five grains of carbonic acid.

II.—The remaining ignited 70 grains were reduced to a most subtle powder, which was

first reduced with water to a pulpy consistence. Half an ounce of strong sulphuric acid was then added; and all the fluid distilled over to dryness. The residue being softened with boiling water, its undissolved portion separated by means of the filter. This being washed, dried, and ignited, yielded $50\frac{1}{2}$ grains of pure silex.

III.—The clear, colourless fluid shewed, by the taste, that it was a solution of sulphate of magnesia. When concentrated by evaporation, it deposited a small quantity of sulphate of lime. This being decomposed by carbonate of ammonia, afforded one grain of carbonated lime, for which half a grain of lime must be reckoned.

IV.—When the sulphate of lime had been separated, the solution yielded, by crystallization, only sulphate of magnesia. From this salt, re-dissolved in water, and decomposed in a boiling heat, by carbonate of potash, $37\frac{1}{2}$ grains of carbonate of magnesia were obtained, which were reduced, after an hour's ignition, to $17\frac{1}{4}$ of magnesia.

An hundred parts of this stone, therefore, contain:

Magnesia.......	17,25
Silex.............	50,50
Lime.............	0,50
Water............	25
Carbonic acid......	5
	98,25

Mr. Klaproth could not accurately ascertain, in the humid way, the proportion of the carbonic acid of this fossil; since acids do not completely dissolve or decompose it in the cold, and hence do not at all effervesce with it, or only imperceptibly. For this reason, he attempted it in the dry way, in the following manner: 200 grains of pulverized silici-murite were introduced into a small glass retort, connected with the mercurial apparatus, and kept in ignition until the vessel was near fusing. The water that passed over was collected in the intermediate vessel or cylinder, while the gas was caught in a receiver above the mercury. The water weighed 35 grains. It was yellowish, and emitted a smell like petroleum; it also manifested a slight vestige of ammonia, which, however, was soon succeeded by a feeble trace of an acid. The gas, deducting

the common air contained in the apparatus, amounted to 13 cubic inches, whose weight is nearly seven grains. This was entirely absorbed by lime-water.

Example 5.—*Analysis of the Semi Indurated Steatite.*

Process I.—Two hundred grains of this steatites, finely scraped with a knife, were subjected to a red heat, in a crucible, during one hour. They lost 11 grains, the ignited powder of the stone received a yellow colour.

II.—This being mixed in a silver crucible with a solution of potash, of which the potash was double the weight of the pulverized stone, and, after having been evaporated to dryness, was kept in ignition for half an hour. The mass was again dissolved in water, and digested with muriatic acid, added in excess. The siliceous earth thus separated weighed 119 grains.

III.—The muriatic solution being mingled with carbonate of potash at a boiling heat. A brownish precipitate was produced. This being treated with muriatic acid, the solution evaporated, and the dry saline mass strongly ignited for half an hour. Having re-dissolved this

saline mass in water, a brown oxid of iron was separated by filtration. The clear solution was combined with carbonate of potash, at the temperature of boiling. By these means, 147 grains of very loose and white sub-carbonate of magnesia were precipitated. One half of this, re-dissolved in sulphuric acid, and crystallized, afforded pure sulphate of magnesia. The other half, when heated to redness, weighed 30½ grains.

IV.—The red oxid of iron, that had separated from the aqueous solution of the ignited saline mass, process III. weighed nine grains. But, as the portion of iron existing in the mixture of steatites cannot be considered in the state of red oxid, but only as being in the state of black oxid of iron, attractible by the magnet, it was deflagrated with linseed oil, in a covered crucible.—This oxid of iron now weighed only five grains.

According to this analysis, the steatites (from Bareuth) consists, in hundred parts, of:

Magnesia	59,50
Silex	30,50
Oxid of Iron	2,50
Water	5,50
	98

Example 6.—*Analysis of the Steatite, or Soap Rock, from Cornwall.*

Process I.—One ounce of it, in select pieces, was exposed to an intense red heat, placing the coated glass retort in open fire. There distilled over a little tasteless water. The steatite lost 75 grains, and acquired a darker colour, and a considerable degree of hardness.

II.—It was next, after previous pulverization, ignited with two ounces of carbonate of potash. The mass was levigated with water, and digested in an excess of muriatic acid. By this means, a large quantity of a white, porous earth, subsided; which being washed, and exposed to a red heat, weighed 204 grains, and was pure siliceous earth.

III.—When the filtered solution had been combined with prussiate of potash, a blue precipitate was produced, which being collected, washed, dried, and ignited with a little wax, yielded oxid of iron attractable by the magnet, and weighing seven grains; of which, on subtracting the portion of iron belonging to the prussiate of potash employed, $3\frac{1}{4}$ grains must be considered as belonging to the steatites.

IV.—From the muriatic solution, freed from

iron, the earthy contents were precipitated by carbonate of potash. The precipitate obtained weighed 192 grains, after being gently ignited. These were covered with a proportionate quantity of distilled vinegar; digested with a low heat, and, lastly, thrown upon the filter. The insoluble part that remained on the paper, and which weighed 93 grains, when dried and ignited, was mixed with three times its weight of sulphuric acid; the mixture evaporated nearly to dryness in a sand heat; the dry saline mass diffused through water; and lastly filtered. By this treatment there yet remained 26 grains of silex.

V.—The sulphuric solution, therefore contained 67 grains of earth; which precipitated by a carbonate alcali, and examined in the usual way, was found to be merely alumine.

VI.—Of the first 192 grains of the earthy precipitate, process IV. 99 grains were taken up by the acetic acid. These were also precipitated by carbonate of potash. The earth thus obtained was assayed by sulphuric acid, and found to be magnesia.

Therefore, one ounce of this steatite from Cornwall yielded:

Magnesia		99 grs.
Silex	{204, 26}	230
Alumine		67
Oxid of iron		3,75
Water		75
		474,75.
	Loss	5,25
		480

Or, an hundred parts of it, averaging the small fractions, contain:

Magnesia	20,50
Silex	48
Alumine	14
Oxid of Iron	1
Water	15,50
	99

TABULAR ARRANGEMENT

OF

MAGNESIAN STONES,

ACCORDING TO THEIR CHEMICAL COMPOSITION AND EXTERNAL CHARACTERS.

Native carbonate of magnesia
Silici-muriacite, meerschaum, or kiffekiel
Nephritic stone, or jade
Green nephrite, or lemanite
Axe stone
Steatite, soap rock, or Spanish chalk
Agalmaltolite, pagodite, or figure stone
Serpentine, commom
Noble serpentine
Potstone
Lithomarge
Friable lithomarge
Indurated lithomarge

Schillerstone
Chlorite, common
Foliated chlorite
Chlorite slate
Earthy chlorite
Green earth
Talc, common
Indurated talc
Earthy talc, or talcite
Foliated, Venetian talc, or Muscovy glass
Asbestus
Amianth, fine fibrous, flexible asbestus, or mountain flax
Byssolite
Ligniform asbestus, or rock wood
Suberiform asbestus, mountain cork, or mountain leather
Actynolite, actinote, or strahlstein
Magnesian spar
Tremolite
Glassy tremolite
Asbestiform tremolite
Chiastolite, crucite, or macle
Olivin, or volcanic chrysolite
Miemite
Boracite, or borate of magnesia

ORDER V.

BARYTIC STONES.

Division of Barytic Stones.

This order comphrehends only two genera, namely:

GENUS I.—*Carbonate of Barytes.*

GENUS II.—*Sulphate of Barytes.*

CHARACTERS OF BARYTIC STONES.

The stones belonging to this order are particularly distinguished by their superior specific gravity, in which they exceed all other stones and earthy minerals. Their specific gravity is four, or at least near to it: exposed to heat they emit a phosphorescent light. They have rather a spongy appearance: they are less hard than siliceous stones, and may be scratched with a knife.

ANALYSIS OF BARYTIC STONES.

Analysis of Carbonate of Barytes.

Process I.—Dissolve a determinate quantity of the mineral, in nitric acid, diluted with 10 of water, and assay a portion of this solution by sulphate of soda; if a precipitate ensues, on adding a small quantity of this salt to the solution of the earth diluted with 20 times its bulk of water, we may conclude that either barytes or strontia is present.

II.—To ascertain which of these earths, (viz. barytes or strontia) is present, or, if both are contained in the solution, to separate them from each other, add sulphate of soda till the precipitate ceases; decant the supernatant liquid; wash the sediment on a filter, and dry it.—Then digest it, with four times its weight of subcarbonate of potash, and a sufficient quantity of water, in a gentle heat, during two or three hours. A double exchange of principles ensues, and we obtain a carbonate of barytes or strontia, or a mixture of both. Pour on these, nitric acid, of the specific gravity 1.4, diluted with an equal weight of distilled water.

This will dissolve the strontia, but not the barytes. To determine whether any strontia has been taken up by the acid, evaporate the solution to dryness, and dissolve the dry mass in alcohol. This alcoholic solution, if it contain nitrate of strontia, will burn with a carmine red flame

Barytes and strontia may also be separated from each other in the following manner: to a saturated solution of the two earths in an acid, add prussiate of potash, which, if pure, will occasion no immediate precipitation; but, after some time, small and insoluble crystals will form on the surface of the jar. These are the prussiate of barytes, which may be changed into the carbonate by a red heat, continued, with the access of air, till the black colour disappears. The strontia may be afterward separated from the solution by carbonate of potash.

A third method of separating strontia from barytes is founded on the stronger affinity of barytes, than of the former earth, for acids. Hence if the two earths be present in the same solution, add a solution of pure barytes till the precipitation ceases. The barytes will seize the acid, and will throw down the strontia.

The strontia solution, in this case, should have no excess of acid, which would prevent the action of the barytic earth.

Having thus ascertained the presence of these earths, evaporate the nitric solution to dryness, and expose it to a red heat in a crucible; the earth thus obtained is barytes; it is soluble in 20 times its weight of water; and if the solution be evaporated, yields crystals of long four-sided prisms. It separates sulphuric acid from all its combinations. If we drop a crystal of this earth into a solution of sulphate of soda, a white precipitate will instantly ensue.

The Analysis of Sulphate of Barytes is analogous to the examination of sulphate of strontia, which shall be noticed presently.

TABULAR ARRANGEMENT

OF

BARYTIC STONES.

Carbonate of barytes, witherite, or barolite
Striated carbonate of barytes
Foliated carbonate of barytes
Sulphate of barytes, or baroselenite
Compact sulphate of barytes
Curved lamellar ditto
Straight lamellar ditto
Columnar ditto
Prismatic, or acicular ditto
Bolognese ditto
Granular ditto

ORDER VI.

STRONTIA STONES.

Division of Strontia Stones.

Of this order of earth there are likewise only two genera known at present. In the one, the strontia earth is combined with carbonic acid; and in the other it is united to sulphuric acid. The first species appears in solid masses; it is composed of long fibres, adhering to each other, and disposed in a radiated manner. Its colour is generally whitish, and asparagus green, which appears deeper towards the centre of the mass. When broken, its surface is a little shining in certain directions; it is brittle, and has a little transparency. Its surface can be scratched with a knife: its specific gravity is from 3.4 to 3.66. The solution of this earth in nitric or muriatic acid, when evaporated to dryness, tinges the flame of alcohol, carmine red.

Sulphate of strontia occurs both amorphous and crystallised, most commonly in bevelled tables, sometimes in rhomboidal cubes, set edge-

ways in the matrix. Its texture is foliated, and more or less transparent. The specific gravity of this mineral reaches from 3.51 to 3.96. Its colour is most commonly reddish, or sky blue, and sometimes colourless.

ANALYSIS OF STRONTIA STONES.

Analysis of Carbonate of Strontia.

Process I.—Dissolve a determinate quantity of the stone supposed to be carbonate of strontia in dilute nitric acid, evaporate the solution, and suffer it to crystallise; collect a portion of these crystals, and, when dry, moisten them with alcohol in a silver spoon. Set fire to the mixture, and hold it while burning over the flame of a candle, so as to cause a quick and rapid combustion. The flame of the alcohol will be tinged beautifully red.

II.—Expose the nitrate of strontia to a red heat, and obtain the earth from this nitrate in a similar manner as directed for obtaining barytes. The earth thus obtained should amount to more than one half of the stone employed.

Analysis of Sulphate of Strontia.

Process I.—Boil one part of sulphate of strontia, reduced to an impalpable powder, with 4 or 6 of carbonate of potash in 12 of water for about two hours, renewing the water as it evaporates, and agitate the mixture frequently.

II.—Decant the supernatant fluid, and wash the insoluble residue in water.

III.—Transfer this insoluble powder into dilute nitric acid, and effect a solution.

IV.—Evaporate the fluid to dryness, and expose it to a red heat: the earth thus obtained is strontia; dissolve it in water; evaporate the solution, and suffer it to crystallise. The remaining fluid may be examined for lime, &c. in the usual manner.

Vauquelin analysed an impure specimen of sulphate of strontia, as follows:

Process I.—On 200 parts of the mineral, diluted nitric acid was poured. A violent effervescence took place, and part of it was dissolved. The undissolved portion, after being heated red hot, weighed 167. Therefore 33 parts were dissolved.

II.—The nitric solution was evaporated to dryness: a reddish substance remained, which indicated the presence of oxid of iron. This substance was re-dissolved in water, and some liquid ammonia mixed with it; a reddish precipitate appeared, which, when dried, weighed one, and was oxid of iron. The remainder of the solution was precipitated by carbonate of potash. The precipitate weighed, when dried, 20, and possessed the properties of carbonate of lime. Therefore 200 parts of this mineral contain 20 of carbonate of lime, one of oxid of iron, and the remainder of the 33 parts he concluded to be water.

III.—The 167 parts, which were insoluble in nitric acid, were mixed with 500 parts of carbonate of potash, and 7000 parts of water, and boiled for a considerable time. The solution was then filtered, and the residuum washed and dried. The liquid scarcely effervesced with acids; but with barytes it produced a copious precipitate, totally insoluble in muriatic acid. Therefore it contained sulphuric acid.

IV.—The undissolved residuum, when dried, weighed 129 parts. It dissolved completely in muriatic acid. The solution crystallized in needles; when dissolved in alcohol, it burnt

with a purple flame; and, in short, had all the properties of muriate of strontia. Therefore these 129 parts were carbonate of strontia. Now, 100 parts of this carbonate contain 30 of carbonic acid; therefore 129 contain 38.7. Hence the mineral must contain in 200 parts 90.3 of strontian.

Now, the insoluble residuum of 167 parts was pure sulphate of strontia: and we have seen that it contained 90.3 of strontia. Therefore the sulphuric acid must amount to 76.7 parts.

TABULAR ARRANGEMENT

OF

STRONTIA STONES.

Carbonate of strontia, or stronianite
Sulphate of strontia, or celestine
Compact sulphate of strontia
Fibrous sulphate of strontia
Foliated sulphate of strontia

ORDER VII.

STONES BELONGING TO THE GLUCINE ORDER.

Division of the Stones belonging to the Glucine order.

This earth has hitherto been found only in three stones, namely; in the Aigue-marine, or Beryl, a transparent stone of a green colour; in the Emerald of Peru, or Smaragd, a stone of a similar colour; and in the Euclase.

ANALYSIS OF THE BERYL, OR EMERALD OF PERU.

Process I.—Take any quantity of beryl or emerald, and having reduced it to a very fine powder, mix it with about three times its weight of potash in a liquid form, and digest it to dryness in a silver crucible, after which let it be moderately ignited for about half an hour: the resulting mass will be found to be entirely soluble in a slight excess of muriatic acid, and the solution, after being evaporated to dryness and

then diffused in water, will deposit nearly the whole of the silex.

II.—The muriatic solution is now to be supersaturated with potash or soda and boiled, by which the oxid of iron and of chrome, if any is present, will be separated.

III.—The clear liquor being again supersaturated with muriatic acid and afterwards mixed at a boiling temperature with carbonate of soda, deposits the whole of its earthy contents in the form of a white soft precipitate.

IV.—This precipitate after being well washed in water, is to be dissolved in sulphuric acid, and the solution being transferred into a ground stoppered bottle is to be considerably supersaturated with carbonate of ammonia: both the alumine and glucine will be at first precipitated, but this last, by the assistance of occasional agitation will be re-dissolved in the course of a few hours.

V.—The earthy residue is to be again dissolved in sulphuric acid, and sulphate of potash being added, a copious deposit of crystals of alum will take place.

VI.—The residuary liquor and washings of the crystals being again treated with a large excess

of carbonated ammonia, the remaining portions of glucine becomes extracted, and the two ammoniacal solutions are to be added together. This fluid when boiled in a retort deposits the whole of the glucine in the state of a white powder, and combined with carbonic acid: after being washed and dried it must be ignited, by which it will lose carbonic acid and moisture to the amount of about half its weight, and the residue is pure glucine.

The remaining earths may be separated according to the rules laid down before, under the articles Analysis of Siliceous and Calcareous Stones.

ORDER VIII.

STONES BELONGING TO THE ZIRCON ORDER.

Division of the Stones belonging to the Zircon order.

There are only two stones hitherto known belonging to this order, namely: Zircon, or Jargon, and the Hyacinth.

ANALYSIS OF THE ZIRCON OR JARGON.

The analysis of this precious stone may be accomplished in the following manner:

Process I.—The mineral being very accurately pulverised is to be mixed with six times its weight of perfectly caustic potash dissolved in a little water. The mass being evaporated to dryness in a silver crucible is to be kept at a low red heat for two hours: after this,

being allowed to cool, it will be found strongly adherent to the crucible, and must accordingly be covered with 10 or 12 times its weight of water, to which must then be added a sufficiency of muriatic acid in order to supersaturate the alcali. By a gentle digestion the whole of the mass will be dissolved, and the clear solution is to be evaporated slowly to dryness, stirring it about all the time to facilitate the separation of the silex.

II.—The residue of the evaporation is now to be digested with a moderate quantity of water slightly acidulated by muriatic acid, which will take up the zircon and oxid of iron, leaving the silex behind. This evaporation and re-solution in very dilute muriatic acid is to be repeated two or three times, that every particle of silex may be separated.

III.—To the muriatic solution is now to be added carbonate of ammonia, which at first occasion an abundant precipitate, but by adding an excess of the alcali the whole of the zircon will be re-dissolved and the oxid of iron falls down to the bottom.

IV.—The clear filtered liquor is to be boiled for two or three hours, by which the excess of ammonia will be driven off, and the zircon

be deposited in the state of carbonate, and in the form of a white powder. This powder being washed and properly dried is afterwards to be ignited, by which about 43 per cent. of water and carbonic acid will be driven off, the remainder being pure zircon.

ORDER IX.

STONES BELONGING TO THE YTTRIA ORDER.

Division of Stones belonging to the Yttria order.

The only mineral known to contain the peculiar earth called Yttria, is Gadolinite.

The mineral called Yttro-Tantalite contains this earth only in a minute quantity, and is properly an ore, belonging to the ores of tantalium, where it has been noticed already.

ANALYSIS OF THE GADOLINITE.

Process I.—Gadolinite being ground to a fine powder is digested with diluted nitric acid, and evaporated to dryness, taking care to increase the heat towards the end of the process, in order to ensure the complete oxidation of the iron, which it always contains in abundance.

II.—The whole is now to be re-dissolved in water, and as the solution still contains a little iron this may be got rid of either by again evaporating to dryness and subsequent digestion in water, or by precipitating the iron by a drop or two of ammonia.

III.—The solution is now mixed with caustic ammonia as long as any precipitate is produced; and the supernatant liquor and washings of the precipitate being mixed with carbonated potash a little carbonate of lime is thrown down.

IV.—The first precipitate of process III. is re-dissolved in nitric acid, and by the cautious and gradual addition of hydro-sulphuret of potash the oxid of manganese is separated.

V.—The clear liquor now only contains nitrate of yttria, from which the earth is procured by caustic ammonia.

VI.—The insoluble residues, process II. consist of silex and oxid of iron, which are separated by muriatic acid, the earth remaining undissolved.

Another method is,

Process I.—To fuse the mineral with twice its weight of caustic potash, to digest the mass

in boiling water, and then separate the liquor while hot from the undissolved portion by the filter.

II.—The fluid will be of a fine green colour, indicating the presence of manganese, and by exposure to the air will become colourless, the oxid of manganese being precipitated in the form of a black powder.

III.—The clear liquor is now to be saturated with nitric acid, and the same fluid very much diluted is to be digested on the insoluble portion, process I. The two nitric solutions being mixed together and evaporated to dryness, and re-digested in water contain only the nitrates of lime and yttria; while the portion insoluble in nitric acid consists of silex and oxid of iron, both of which are to be separated in the manner already described.

ANALYSIS

OF

SOILS.

In the preceding pages it has been endeavoured to exhibit a view of analysing earths and stones, as constituting particular orders or genera, and species; we shall now consider the method of analysing soils.

Land, considered as the basis of vegetation, is called *soil*. Soils consist of different combinations of earths, intermingled with a portion of animal and vegetable matter.

The following abstract, for determining the composition of a soil, are copied from a Memoir, presented by Mr. Davy to the Board of Agriculture.

1.—*Utility of investigation relating to the Analysis of Soils.*—The methods of improving lands are immediately connected with the knowledge of the chemical nature of soils, and experiments on their composition appear capable of many useful applications.

The importance of this subject has been already felt by some very able cultivators of science: many useful facts and observations, with regard to it, have been furnished by Mr. Young; it has been examined by Lord Dundonald, in his treatise on the Connexion of Chemistry with Agriculture, and by Mr. Kirwan, in his excellent essay on manures: but the enquiry is still far from being exhausted, and new methods of elucidating it are almost continually offered, in consequence of the rapid progress of chemical discovery.

In the following pages I shall have the honor of laying before the board an account of those methods of analysing soils which appear most precise and simple, and most likely to be useful to the practical farmer; they are founded partly upon the labours of the gentlemen whose names have been just mentioned, and partly upon some later improvements.

The substances which are found in soils are certain mixtures or combinations of some of the primitive earths, animal or vegetable matter in a decomposing state, certain saline compounds, and the oxid of iron. These bodies always retain water, and exist in very different proportions in different lands; and the end of analytical experiments is the detection of their quantities and mode of union.

2.—*Mode of collecting Soils for Analysis.*—In cases when the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places, two or three inches below the surface, and examined as to the similarity of their properties. It sometimes happens that upon plains the whole of the upper stratum of the land is of the same kind, and in this case one analysis will be sufficient; but in valleys, and near the beds of rivers, there are very great differences, and it now and then occurs that one part of a field is calcareous, and another part siliceous; and in this case, and in analogous cases, the portions different from each other should be separately submitted to experiment.

Soils, when collected, if they cannot be immediately examined, should be preserved in phials quite filled with them, and closed with ground glass stoppers.

The quantity of soil most convenient for a perfect analysis is from two to four hundred grains. It should be collected in dry weather, and exposed to the atmosphere till it becomes dry to the touch.

The specific gravity of a soil, or the relation of its weight to that of water, may be ascertained by introducing into a phial, which will contain a known quantity of water, equal volumes of water and of soil; and this may be easily done by pouring in water till it is half full, and then adding the soil till the fluid rises to the mouth; the difference between the weight of the soil and that of the water will give the result. Thus if the bottle contains four hundred grains of water, and gains two hundred grains when half filled with water and half with soil, the specific gravity of the soil will be 2, that is, it will be twice as heavy as water, and if it gained one hundred and sixty-five grains, its specific gravity would be 1825, water being 1000.

It is of importance, that the specific gravity of a soil should be known, as it affords an indication of the quantity of animal and vegetable matter it contains: these substances being always most abundant in the lighter soils.

The other physical properties of soils should likewise be examined before the analysis is made, as they denote to a certain extent their composition, and serve as guides in directing the experiments. Thus siliceous soils are generally rough to the touch, and scratch glass when rubbed upon it; argillaceous soils adhere strongly to the tongue, and emit a strong earthy smell when breathed on; and calcareous soils are soft, and much less adhesive than argillaceous soils.

3.—*Mode of ascertaining the quantity of Water of Absorption in Soils.*—Soils, though as dry as they can be made by continued exposure to the air, in all cases still contain a considerable quantity of water, which adheres with great obstinacy to the earths and animal and vegetable matter, and can only be driven off from them by a considerable degree of heat. The first process of analysis is, to free the given weight of soil from as much of this water as

possible, without in other respects affecting its composition; and this may be done by heating it for ten or twelve minutes over an Argand's lamp, in a bason of porcelain, to a temperature equal to 300.* Fahrenheit; and in case a thermometer is not used, the proper degree may be easily ascertained, by keeping a piece of wood in contact with the bottom of the dish: as long as the colour of the wood remains unaltered, the heat is not too high; but when the wood begins to be charred, the process must be stopped. A small quantity of water will perhaps remain in the soil even after this operation, but it always affords useful comparative results; and if a higher temperature were employed, the vegetable or animal matter would undergo decomposition, and in consequence the experiment be wholly unsatisfactory.

The loss of weight in the process should be carefully noted; and when in four hundred grains of soil it reaches as high as 50, the soil may be considered as in the greatest degree absorbent, and retentive of water, and will ge-

* In several experiments, in which this process has been carried on by distillation, I have found the water that came over pure, and no sensible quantity of other volatile matter was produced.

nerally be found to contain a large proportion of alumine. When the loss is only from 20 to 10, the land may be considered as only slightly absorbent and retentive, and the siliceous earth as most abundant.

4.—*Of the separation of Stones, Gravel, and vegetable fibres, from Soils.*—None of the loose stones, gravel, or large vegetable fibres, should be divided from the pure soil till after the water is drawn off: for these bodies are themselves often highly absorbent and retentive, and in consequence influence the fertility of the land. The next process, however, after that of heating, should be their separation, which may be easily accomplished by the sieve, after the soil has been gently bruised in a mortar. The weights of the vegetable fibres or wood, and of the gravel and stones, should be separately noted down, and the nature of the last ascertained; if calcareous, they will effervesce with acid; if siliceous, they will be sufficiently hard to scratch glass; and if of the common argillaceous class of stones, they will be soft, easily scratched with a knife, and incapable of effervescing with acids.

5.—*Separation of the Sand and Clay, or Loam, from each other.*—The greatest number of soils, besides gravel and stones, contain larger or smaller proportions of sand of different degrees of fineness; and it is a necessary operation, the next in the process of analysis, to detach them from the parts in a state of more minute division, such as clay, loam, marle, and vegetable and animal matter. This may be effected in a way sufficiently accurate, by agitating the soil in water. In this case, the coarse sand will generally separate in a minute, and the finer in two or three minutes, whilst the minutely divided earthy, animal, or vegetable matter, will remain in a state of mechanical suspension for a much longer time; so that, by pouring the water from the bottom of the vessel, after one, two, or three minutes, the sand will be principally separated from the other substances, which, with the water containing them, must be poured into a filter, and after the water has passed through, collected, dried, and weighed; the sand must likewise be weighed, and their respective quantities noted down. The water of lixiviation must be preserved, as it will be found to contain the saline matter, and the soluble animal and vegetable matters, if any exist in the soil.

6.—*Examination of the Sand.*—By the process of washing and filtration, the soil is separated into two portions, the most important of which is generally the finely divided matter. A minute analysis of the sand is seldom or never necessary, and its nature may be detected in the same manner as that of the stones or gravel. It is always either siliceous sand or calcareous sand, or a mixture of both. If it consist wholly of carbonate of lime, it will be rapidly soluble in muriatic acid, with effervescence; but if it consist partly of this substance and partly of siliceous matter, the respective quantities may be ascertained by weighing the residuum after the action of the acid, which must be applied till the mixture has acquired a sour taste, and has ceased to effervesce. This residuum is the siliceous part: it must be washed, dried, and heated strongly in a crucible; the difference between the weight of it and the weight of the whole indicates the proportion of calcareous sand.

7.—*Examination of the finely divided Matter of Soils, and mode of detecting Mild Lime and Magnesia.*—The finely divided matter of the soil is usually very compound in its nature; it

sometimes contains all the four primitive earths of soils, as well as animal and vegetable matter; and to ascertain the proportions of these with tolerable accuracy is the most difficult part of the subject.

The first process to be performed, in this part of the analysis, is the exposure of the fine matter of the soil to the action of the muriatic acid. This substance should be poured upon the earthy matter in an evaporating bason, in a quantity equal to twice the weight of the earthy matter, but diluted with double its volume of water. The mixture should be often stirred, and suffered to remain for an hour, or an hour and a half, before it is examined.

If any carbonate of lime or of magnesia exist in the soil, they will have been dissolved in this time by the acid, which sometimes takes up likewise a little oxid of iron, but very seldom any alumine.

The fluid should be passed through a filter; the solid matter collected, washed with rain water, dried at a moderate heat, and weighed. Its loss will denote the quantity of solid matter taken up. The washings must be added to the solutions, which, if not sour to the taste, must be made so by the addition of fresh acid, when

a little solution of common prussiate of potash must be mixed with the whole. If a blue precipitate occurs, it denotes the presence of oxid of iron, and the solution of the prussiate must be dropped in till no further effect is produced. To ascertain its quantity it must be collected in the same manner as other solid precipitates, and heated red; the result is oxid of iron.

Into the fluid, freed from oxid of iron, a solution of neutralized carbonate of potash must be poured till all effervescence ceases in it, and till its taste and smell indicate a considerable excess of alcaline salt.

The precipitate that falls down is carbonate of lime; it must be collected on the filter, and dried at a heat below that of redness.

The remaining fluid must be boiled for a quarter of an hour, when the magnesia, if any exist, will be precipitated from it, combined with carbonic acid; and its quantity is to be ascertained in the same manner as that of the carbonate of lime.

If any minute proportion of alumine should, from peculiar circumstances, be dissolved by the acid, it will be found in the precipitate with the carbonate of lime, and it may be separated from it by boiling for a few minutes with caustic

potash, sufficient to cover the solid matter. This substance dissolves alumine, without acting upon carbonate of lime.

Should the finely divided soil be sufficiently calcareous to effervesce very strongly with acids, a very simple method may be adopted for ascertaining the quantity of carbonate of lime, and one sufficiently accurate in all common cases.

Carbonate of lime, in all its states, contains a determinate proportion of carbonic acid, *i. e.* about 45 per cent. so that when the quantity of this elastic fluid, given out by any soil during the solution of its calcareous matter in an acid, is unknown, either in weight or measure, the quantity of carbonate of lime may be easily discovered.

When the process by diminution of weight is employed, two parts of the acid, and one part of the matter of the soil, must be weighed in two separate bottles, and very slowly mixed together till the effervescence ceases: the difference between their weight before and after the experiment denotes the quantity of carbonic acid lost; for every four grains and a half of which, ten grains of carbonate of lime must be estimated.

The best method of collecting the carbonic acid, so as to discover its volume, is by the pneumatic apparatus, the construction and application of which is described at the end of this paper. The estimation is, for every ounce measure of carbonic acid two grains of carbonate of lime.

8.—*Mode of ascertaining the quantity of insoluble finely divided Animal and Vegetable Matter.*—After the fine matter of the soil has been acted upon by muriatic acid, the next process is to ascertain the quantity of finely divided insoluble animal and vegetable matter that it contains.

This may be done with sufficient precision, by heating it to strong ignition in a crucible over a common fire till no blackness remains in the mass. It should be often stirred with a metallic wire, so as to expose new surfaces continually to the air; the loss of weight that it undergoes denotes the quantity of the substance that it contains destructible by fire and air.

It is not possible to ascertain whether this substance is wholly animal or vegetable matter, or a mixture of both. When the smell emitted

during the incineration is similar to that of burnt feathers, it is a certain indication of some animal matter; and a copious blue flame at the time of ignition almost always denotes a considerable portion of vegetable matter. In cases when the experiment is needed to be very quickly performed, the destruction of the decomposible substances may be assisted by the agency of nitrate of ammonia, which, at the time of ignition, may be thrown gradually upon the heated mass, in the quantity of twenty grains for every hundred of residual soil. It affords the principle necessary to the combustion of the animal and vegetable matter, which it causes to be converted into elastic fluids; and is itself at the same time decomposed and lost.

9.—*Mode of separating argillaceous and Siliceous Matter, and Oxid of Iron.*—The substances remaining after the decomposition of the vegetable and animal matter are generally minute particles of earthy matter, containing usually alumine and silex with combined oxid of iron.

To separate these from each other, the solid matter should be boiled for two or three hours with sulphuric acid, diluted with four times its

weight of water; the quantity of the acid should be regulated by the quantity of solid residuum to be acted on, allowing for every hundred grains two drachms, or one hundred and twenty grains of acid.

The substance remaining after the action of the acid may be considered as siliceous; and it must be separated, and its weight ascertained, after washing and drying in the usual manner.

The alumine and the oxid of iron, if any exist, are both dissolved by the sulphuric acid; they may be separated by carbonate of ammoniac, added to excess: it throws down the alumine, and leaves the oxid of iron in solution, and this substance may be separated from the liquid by boiling.

Should any magnesia and lime have escaped solution in the muriatic acid, they will be found in the sulphuric acid: this, however, is scarcely ever the case; but the process for detecting them and ascertaining their quantities is the same in both instances.

The method of analysis by sulphuric acid is sufficiently precise for all usual experiments; but if very great accuracy be an object, dry carbonate of potash must be employed as the agent,

and the residuum of the incineration must be heated red for half an hour, with four times its weight of this substance, in a crucible of silver, or of well-baked porcelain. The mass obtained must be dissolved in muriatic acid, and the solution evaporated till it is nearly solid; distilled water must then be added, by which the oxid of iron and all the earths, except silex, will be dissolved in combination as muriates. The silex, after the usual process of lixiviation, must be heated red; the other substances may be separated in the same manner as from the muriatic and sulphuric solutions.

This process is the one usually employed by chemical philosophers for the analysis of stones.

10.—*Mode of discovering Soluble Animal and Vegetable Matter, and Saline Substances.*—If any saline matter or soluble vegetable or animal matter, is suspected in the soil, it will be found in the water of lixiviation used for separating the sand.

This water must be evaporated to dryness in an appropriate dish, at a heat below its boiling point.

If the solid matter obtained is of a brown colour, and inflammable, it may be considered

as partly vegetable extract. If its smell, when exposed to heat, be strong and fetid, it contains animal mucilaginous or gelatinous substance; if it be white and transparent, it may be considered as principally saline matter. Nitrate of potash (nitre), or nitrate of lime, is indicated in this saline matter, by its scintillating with a burning coal. Sulphate of magnesia may be detected by its bitter taste; and sulphate of potash produces no alteration in solution of carbonate of ammonia, but precipitate solution of muriate of barytes.

11.—*Mode of detecting sulphate of Lime (Gypsum) and Phosphate of Lime in Soils.*— Should sulphate or phosphate of lime be suspected in the entire soil, the detection of them requires a particular process upon it. A given weight of it, for instance four hundred grains, must be heated red for half an hour in a crucible, mixed with one-third of powdered charcoal. The mixture must be boiled for a quarter of an hour in a half pint of water, and the fluid collected through the filter, and exposed for some days to the atmosphere in an open vessel. If any soluble quantity of sulphate of lime

(gypsum) existed in the soil, a white precipitate will gradually form in the fluid, and the weight of it will indicate the proportion.

Phosphate of lime, if any exist, may be separated from the soil after the process of gypsum: Muriatic acid must be digested upon the soil, in quantity more than sufficient to saturate the soluble earths; the solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths with the muriatic acid, and leave the phosphate of lime untouched.

12.—*Statement of Results and Products.*—When the examination of a soil is completed, the products should be classed, and their quantities added together; and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must, however, be noticed, that when phosphate, or sulphate, of lime is discovered by the independent process 11, a correction must be made for the independent process, by subtracting a sum equal to its weight from the quantity of carbonate of lime obtained by precipitation from the muriatic acid.

In arranging the products, the form should be

in the order of the experiments by which they are obtained.

Thus 400 grains of a good siliceous sandy soil may be supposed to contain

		Grains.
Of water of absorption		18
Of loose stone and gravel, principally siliceous		42
Of undecompounded vegetable fibres		10
Of fine siliceous sand		200
Of minutely divided matter separated by filtration, and consisting of		
Carbonate of lime	25	
Carbonate of magnesia	4	
Matter destructible by heat, principally vegetable	10	
Silex	40	
Alumine	33	
Oxid of Iron	4	
Soluble matter, principally sulphate of potash and vegetable extract	5	
Gypsum	3	
Phosphate of lime	2	
		126
Amount of all the products		395
Loss		4

In this instance the loss is supposed small; but, in general, in actual experiments, it will be found much greater, in consequence of the difficulty of collecting the whole quantities of the different precipitates; and when it is within thirty for four hundred grains, there is no reason to suspect any want of due precision in the processes.

13.—*This general Method of Analysis, may, in many cases, be much simplified.*—When the experimenter is become acquainted with the use of the different instruments, the properties of the re-agents, and the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid, 7, may be omitted. In examining peat soils, he will principally have to attend to the operation by fire and air, 8; and in the analysis of chalks and loams, he will be often able to omit the experiment by sulphuric acid, 9.

In the first trials that are made by persons unacquainted with chemistry, they must not

expect much precision of result. Many difficulties will be met with: but, in overcoming them, the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but perhaps there is no better mode of gaining it than that of attempting original investigations. In pursuing his experiments, he will be continually obliged to learn from books the history of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operation, and acquired for the purpose of discovery.

14.—*On the improvement of Soils, as connected with the principle of their composition.*—In cases when a barren soil is examined with a view to its improvement, it ought, in all cases, if possible, to be compared with an extremely fertile soil in the same neighbourhood, and in a similar situation: the difference given by their analysis would indicate the methods of cultivation; and thus the plan of improvement would be founded upon accurate scientific principles.

If the fertile soil contained a large quantity of sand in proportion to the barren soil, the process of amelioration would depend simply upon a supply of this substance; and the method would be equally simple with regard to soils deficient in clay or calcareous matter.

In the application of clay, sand, loam, marle, or chalk, to lands, there are no particular chemical principles to be observed; but when quick lime is used, great care must be taken that it is not obtained from the magnesian limestone; for in this case, as has been shewn by Mr. Tennant, it is exceedingly injurious to land.* The magnesian limestone may be distinguished from the common limestone by its greater hardness, and by the length of time that it requires for its solution in acids; and it may be analysed by the process of carbonate of lime and magnesia, 7.

When the analytical comparison indicates an excess of vegetable matter, as the cause of sterility, it may be destroyed by much pulverisation and exposure to air, by paring and burning, or the agency of lately made quick-lime. And the

* Philosoph. Trans. for 1799, p: 305. This limestone is found abundantly in Yorkshire, Derbyshire, and Somersetshire.

defect of animal and vegetable matter must be supplied by animal or vegetable manure.

15.—*Sterile Soils in different climates and situations must differ in composition.*—The general indications of fertility and barrenness, as found by chemical experiments, necessarily must differ in different climates, and under different circumstances. The power of soils absorb moisture, a principle essential to their productiveness, ought to be much greater in warm and dry countries than in cold and moist ones; and the quantity of fine aluminous earth they contain larger. Soils, likewise, that are situated on declivities, ought to be more absorbent than those in the same climate on plains or in valleys.* The productiveness of soils must likewise be influenced by the nature of the subsoil, or the earthy or stony strata on which they rest; and this circumstance ought to be particularly attended to, in considering their chemical nature, and the system of improvement. Thus a sandy soil may sometimes owe its fertility to the power of the subsoil to retain water; and an absorbent clayey soil may

* Kirwan, Trans. Irish Academy, Vol. V. p. 175.

occasionally be prevented from being barren, in a moist climate by the influence of a substratum of sand or gravel.

16.—*Of the chemical composition of fertile Corn Soils in this climate.*—Those soils that are most productive of corn contain always certain proportions of aluminous and calcareous earth in a finely divided state, and a certain quantity of vegetable or animal matter.

The quantity of calcareous earth is, however, very various, and, in some cases, exceedingly small. A very fertile corn soil from Ormiston, in East Lothian, afforded me, in an hundred parts, only eleven parts of mild calcareous earth; it contained twenty-five parts of siliceous sand; the finely divided clay amounted to forty-five parts. It lost nine in decomposed animal and vegetable matter, and four in water, and afforded indications of a small quantity of phosphate of lime.

This soil was of a very fine texture, and contained very few stones or vegetable fibres. It is not unlikely that its fertility was in some measure connected with the phosphate; for this substance is found in wheat, oats, and barley, and may be a part of their food.

A soil from the low lands of Somersetshire, celebrated for producing excellent crops of wheat and beans without manure, I found to consist of one-ninth of sand, chiefly siliceous, and eight-ninths of calcareous marl, tinged with iron, and containing about five parts in the hundred of vegetable matter. I could not detect in it any phosphate or sulphate of lime, so that its fertility must have depended principally upon its power of attracting principles of vegetable nourishment from water and the atmosphere.*

Mr. Tillet, in some experiments made on the composition of soils at Paris, found that a soil composed of three-eighths of clay, two-eighths of river sand, and three-eighth of the parings of lime-stone, was very proper for wheat.

17.—*Of the composition of Soils proper for bulbous roots and for trees*—In general, bulbous roots require a soil much more sandy, and less absorbent than the grasses. A very good potatoe soil, from Varfal, in Cornwall, afforded me seven-eighths of siliceous sand; and its absorbent

* This soil was sent to me by T. Poole, Esq. of Nether Stowey. It is near the opening of the river Parret into the British Channel; but, I am told, is never overflowed.

power was so small, that one hundred parts lost only two by drying at 400° Fahrenheit.

Plants and trees, the roots of which are fibrous and hard, and capable of penetrating deep into the earth, will vegetate to advantage in almost all common soils, which are moderately dry, and which do not contain a very great excess of vegetable matter.

I found the soil taken from a field at Sheffield Place, in Sussex, remarkable for producing flourishing oaks, to consist of six parts of sand, and one part of clay and finely divided matter; and one hundred parts of the entire soil, submitted to analysis, produced,

Water	3 parts
Silex	54
Alumine	28
Carbonate of lime	3
Oxid of iron	5
Decomposing vegetable matter	4
Loss	3

18.—*Advantages of Improvements made by changing the Composition of earthy Parts of Soils.*—From the great difference of the causes that influence the productiveness of lands, it is

obvious, that, in the present state of science, no certain system can be devised for their improvement, independent of experiment; but there are few cases in which the labour of analytical trials will not be amply repaid by the certainty with which they denote the best methods of amelioration; and this will particularly happen when the defect of composition is found in the proportions of the primitive earths.

In supplying animal or vegetable manure a temporary food only is provided for plants, which is in all cases exhausted by means of a certain number of crops: but when a soil is rendered of the best possible constitution and texture, with regard to its earthy parts, its fertility may be considered as permanently established. It becomes capable of attracting a very large portion of vegetable nourishment from the atmosphere, and of producing its crops with comparatively little labour and expence.

Description of the Apparatus for the Analysis of Soils.—Fig. 1, Plate I. *a*, *b*, *c*, *d*, *e*, *f*. The different parts of the apparatus required for measuring the quantity of elastic fluid given out during the action of an acid on calcareous soils:

a, represents the bottle for containing the soil; *b*, the bottle containing the acid, furnished with a stop-cock; *c*, the tube connected with a flaccid bladder; *f*, the graduated measure; *f*, *e*, the bottle for containing the bladder *d*. When this instrument is used, a given quantity of soil is introduced into *a*; *b* is filled with muriatic acid, diluted with an equal quantity of water; and the stop-cock being closed, is connected with the upper orifice of *a*, which is ground to receive it. The tube *c* is introduced into the lower orifice of *a*, and the bladder connected with it placed in its flaccid state in *e*, *f*, which is filled with water. The graduated measure is placed under the spout of *f e*. When the stop-cock of *b* is turned, the acid flows into *a*, and acts upon the soil; the elastic fluid generated passes through *c* into the bladder, and displaces a quantity of water in *e f* equal to it in bulk, and this water flows through the tube or spout into the graduated measure; the water in which gives, by its volume, the indication of the proportion of carbonic acid disengaged from the soil; for every ounce measure of which, two grains of carbonate of lime may be estimated.

PART IV.

CLASS 3.

MINERAL OR NATIVE SALTS.

By the name of mineral or native salts, we understand, strictly speaking, all those native mineral substances which are found, consisting of an earthy, metallic, or alcaline base, combined with an acid. They naturally divide themselves into several genera, namely; calcareous salts, comprehending the combination of calcareous earth, with different acids; such as carbonates, sulphates, phosphates, fluates, and borates of lime: Barytic salts, comprehending the combinations of barytic earth, with sulphuric and carbonic acids; strontian salts, or strontian earth, united to the same acids, &c. Most of these

have been considered under the class of earths, and stones. We have therefore to consider here merely those which are readily soluble in water, and which are usually called mineral salts; for they possess the properties of saline bodies, in a more striking degree. They are divided in the Chemical Systems of Mineralogy, in the following manner:

Division of Mineral or Native Salts.

GENUS I.—*Muriates.*

Species 1.—Muriate of Soda, or Common Salt.

Varieties 1.—Foliated Common Salt.
2.—Fibrous Common Salt.
3.—Lake Salt
4.—Rock or Stone Salt.

GENUS II.—*Muriates.*

Species 1.—Muriate of Ammonia, or Native Sal Ammoniac.

GENUS III.—*Nitrates.*

Species 1.—Nitrate of Soda, or Native Saltpetre.

GENUS IV.—*Sulphates.*

Species 1.—Sulphate of Soda, or Native Glauber Salt.
2.—Sulphate of Magnesia, or Native Epsom Salt.
3.—Sulphate of Magnesia and Iron, or Hair Salt.
4.—Sulphate of Alumine and Soda, or Native Alum
5.—Sulphate of Iron, or Native Vitriol.
6.—Sulphate of Copper.
7.—Sulphate of Zinc.
8.—Sulphate of Cobalt.

GENUS V.—*Borates.*

Species 1.—Borate of Soda, or Native Borax.
2.—Borate of Magnesia and Lime, or Salsoline.

GENUS VI.—*Carbonates.*

Species 1.—Carbonate of Soda, or Native Natron.

GENUS VII.—*Boracic Acid.*

GENERAL ANALYSIS OF NATIVE OR MINERAL SALTS.

Process I.—In order to investigate whether an unknown mineral contains some saline matter, put a determinate quantity, reduced to an impalpable powder, into a flask, pour over it 30 times its weight of water, digest the mixture in a temperature of about 130°, and agitate it frequently. Having stood for about 6 hours, decant the transparent fluid, separate the insoluble part, by pouring it on a filter, whose weight is known; dry it in a heat not exceeding 212°, and ascertain its weight. If the weight be considerably less than the joint weight of the filter and powder, before digestion, we are certain that some salt has been taken up by the water; the deficiency of weight will indicate its quantity. Being thus convinced, that the substance under examination belongs to the class of minerals, properly called salts, we have next to find out the nature of it, more accurately, in the following manner:

II.—Drop into a wine-glass full of the solution, obtained by digesting the mineral in water, as directed before, a few drops of tincture of

litmus, or immerse into it a piece of litmus paper, and notice if the blue colour of the tincture, or of the paper, becomes altered, or not.

If the paper becomes red, the fluid contains an uncombined acid, or a salt with excess of acid. In order to ascertain the nature of the acid which is present, drop into the solution muriate of barytes; if an insoluble precipitate ensues, sulphuric acid is present; but if the precipitate is soluble in muriatic acid, phosphoric acid may be expected. If nitrate of silver occasions a precipitate, muriatic salts, or muriatic acid was present.

III.—If water that has been suffered to act on a saline substance, changes the yellow colour of turmeric paper brown, it contains an alcaline substance, and the salt belongs to the class of alcaline salts.

IV.—If a substance is found not to change the colour of the turmeric brown, or that of litmus red, and if it does not effervesce on the addition of an alcali, the salt is then distinguished to be a neutral, or compound salt, composed of an acid, and a certain base: we have then to determine the nature of the base, that is to say, to find out whether the salt has

a metallic, earthy, or an alcali for its basis. This may be accomplished in the following manner:

ANALYSIS OF SALTS WITH METALLIC BASES.

Process I.—Drop into the solution, obtained as described before, a few drops of prussiate of potash; if a copious blue precipitate ensues, it then contains a metallic oxid, and belongs to the salts called metallic salts.

II.—To ascertain the genus to which it belongs, by determining the acid whereby its basis is neutralized, add to a little of the saturated saline solution, an equal portion of alcohol; if this occasions the salt to precipitate, and if a few drops of muriate of barytes, added to a little of the dissolved salt, occasion a copious precipitate, we know that the acid present is sulphuric acid, and that the salt belongs to the genus called *sulphates*.

III.—To determine the metallic oxid, with which the acid was combined, we add to it first a solution of carbonate of ammonia; if this occasion a blue precipitate, which is redissolved by an excess of ammonia, add an acid, a little in excess; we then immerse into

it a cylinder of iron, and suffer it to stand undisturbed for some days. If the iron cylinder becomes covered with a coat of copper, we then have found that the salt had copper for its basis, and therefore belonged to that species which is called *sulphate of copper.*

IV.—But if these phenomena are not perceived, we let fall into the solution a few drops of prussiate of potash. If this produces a blue precipitate, the basis is then supposed to be iron, and in this case it must also occasion a black colour when mixed with tincture of galls. If such phenomena take place, the salt belongs to that species called *sulphate of iron.*

V.—If neither of these phenomena ensue, and the fluid exhibits a rose colour, we add a few drops of tincture of galls; if this occasions a blue precipitate, and a precipitate is also produced by the addition of potash, which, when fused with borax before the blow-pipe, produces a blue glass, we then have ascertained the basis of the salt to be cobalt, and this with sulphuric acid before detected, makes it to be that species called *sulphate of cobalt.*

VI.—If neither of these marks should be perceived, we place a polished cylinder of copper into the concentrated solution; and if this

occasions a white metallic precipitate upon the surface of the copper cylinder, which can be volatilized again by exposing the cylinder to heat, we then know the basis to be mercury; having ascertained the principal component part of the salt, which is distinguished by the name of *sulphate of mercury*.

VII.—But if the fluid should not prove any of these mentioned properties of mixture, and if it yields a white salt on evaporation, if prussiate of potash added to it, produces a greenish white precipitate, and if a cylinder of iron, and copper, when placed in the solution, occasions no precipitate, we then suppose the substance to be the species called *sulphate of zinc*. These are the principal metallic salts hitherto found in the earth.

ANALYSIS OF SALTS WITH ALCALINE BASES.

Process I.—If in a solution of salt prussiate of potash does not occasion a blue precipitate, the salt is of a different nature from those mentioned before. We have then to find out its composition, by adding to it a solution of subcarbonate of potash, or soda. If this occasions no precipitate, the salt then probably belongs to

the neutral salts, with alcaline bases. It may, however, happen, that salts of that kind exist in the solution, associated with salts of a metallic or earthy base. In this case the examination becomes difficult; because the alcali added, which acts as the re-agent to precipitate the two last, makes it doubtful to ascertain whether the neutral salts were formed during the process, or whether they originally existed in the solution. The following method, recommended by Mr. Henry, will in that case prove useful.

II.—Precipitate the metallic oxid, by adding to the solution prussiate of ammonia, and separate the earth, by adding to it a solution of carbonate of ammonia, taking care to have previously heated the fluid to at least 180°, or upwards, in order to insure the decomposition of magnesian salts, which cannot be effected by carbonate of ammonia in the cold. Separate the liquor by filtration, and evaporate it to dryness; then expose the dry mass to a dull red heat, in order to expel the ammoniacal salts. The salts, with fixed alcaline bases, will remain behind. By this process, indeed it will be impossible to ascertain whether ammoniacal salts were originally present; but this may be learned by adding to the salt under examination, before its

solution in water, some potash, which, if ammonia be contained in the salt, will produce its peculiar odour.

III.—In order to ascertain the acid with which the ammonia is combined, we mingle a solution of the salt with lime-water. If a precipitate ensues, which on adding a few drops of muriatic acid, again becomes dissolved with effervescence, the salt belonged to the class of salts, called *carbonate of ammonia.*

IV.—If on the contrary no such effects take place, but a copious precipitate ensues on adding to the solution a few drops of muriate of barytes, we then conclude that the salts is *sulphate of ammonia.*

V.—But if neither of these changes ensue, we drop into the solution a few drops of sulphate of silver; if this produces an insoluble white precipitate, the salts consist of muriatic acid and ammonia, and is consequently *muriate of ammonia.*

VI.—But suppose ammonia did not enter into the composition of the salt, and had not been detected as stated before, but another alcaline basis was present, we then add to the solution of the salt in water a few drops of muriate of platina: if a turbidness ensues, the basis of the salt is

potash, and the salt of course belongs to the class of salts with a basis of *vegetable alcali*; but if no such effect takes place, we conclude that the basis of the salt is soda, and that it belongs to the class of salts, with a basis of the *mineral alcali*.

VIII.—If a little of the salt, when mixt with charcoal powder, and thrown into an ignited crucible deflagrates, we know that nitric acid is present, and that it belongs to the class of salts called *nitrates*.

The presence of other acids may be detected as stated before.

ANALYSIS OF SALTS WITH EARTHY BASES.

Process I.—If a solution of salt, in which prussiate of potash occasions no precipitate, affords a copious precipitate by the addition of carbonate of potash, it proves that the salt has an earth for its basis, and consequently belongs to the class of *earthy salts*.

II.—In order to ascertain the acid which is combined with the earth, we proceed as directed in the preceding pages.

III.—We next endeavour to ascertain the earths: if we find that the precipitate is soluble in sulphuric acid, and yields with it, by the addition of a small quantity of alcali, a salt which has a sweet styptic taste, and which has the properties of alum, we know that the basis of the salt was alumine, and that it belongs to the class of *salts*, called *alum*.

IV.—But if the salt obtained by neutralizing the earth with sulphuric acid has a bitterish taste, and becomes decomposed by sub-carbonate of potash, and yields a precipitate which when ignited remains soluble in nitric and acetic acids; it then belongs to the class of salts, having magnesia for its basis, called *magnesian salts*.

In this manner we may ascertain the different salts which have hitherto been found amongst the mineral substances. There are others met with in mineral waters, the presence and nature of which must be ascertained in a different manner. The salts here considered are only such as are found each in a separate state, and which appear homogenous.

Before we conclude this subject we shall exhibit an

EXAMPLE OF AN ANALYSIS OF A MIXTURE OF DIFFERENT SALINE SUBSTANCES.

Suppose we had ascertained by previous experiments, in the way mentioned in the foregoing part, that an earth contained a mixture of different salts, viz. *sulphate of magnesia, muriate of potash, sulphate of iron, sulphate of potash,* and, *sulphate of soda*; we then may proceed in the following way:

Process I.—Let a certain quantity of such earthy substance which has been previously dried for two hours in the heat of boiling water, be extracted and freed from saline parts, by digesting it with about 50 parts of distilled water, in a glass matrass; filter the whole, and wash the remainder upon the filter, with a little water, then dry it in the same heat, and for the same time as before, and ascertain its weight. The loss, indicates the quantity of saline parts which were contained in it.

II.—Let a certain quantity of the saline liquid be evaporated to dryness by a gentle heat.

III.—Digest the residue with high rectified spirit of wine, as long as the spirit will dissolve

any part of the salt. This spirituous solution mix with a little water, and again separate the spirit by distillation.

IV.—Evaporate the remaining aqueous solution nearly to dryness, and suffer it to crystallise; let the salt be dried in the same degree of heat as the earth had been exposed, and ascertain its weight, which will indicate the proportion of the salt which was taken up by the spirit, and which was muriate of potash; this salt may be again decomposed, by dissolving a little of it in water, and adding to it sulphate of silver: this will occasion a precipitate which indicates the muriatic acid; and carbonate of potash added to it, will occasion no earthy precipitate, if the salt was merely composed of muriatic acid and potash.

V.—The salt which was not acted upon by the spirit, is then to be dissolved with a sufficient quantity of distilled water, mingled with a little acetous acid, and prussiate of lime gradually dropped into it, until it does not occasion any more blue precipitate. The precipitate thus formed, must be collected on a filter, washed with a little water, dried, and made red hot in a small crucible, whose weight is previously ascertained, and which has been ignited before

the precipitate was put in; after which, the crucible is taken out of the fire and again weighed, thus the proportion of the oxid of iron is ascertained.

VI.—The remaining liquid from which the iron is separated, is gradually to be mixed with acetite of barytes as long as any precipitate is thereby occasioned: the precipitate consists of the barytes contained in the acetous solution which was added, and of the sulphuric acid contained in the salts; the whole is then put upon a filter, the precipitate carefully collected, dried, and its weight ascertained. One hundred grains of such precipitate, are equal to 23.5 grains of sulphuric acid.

VII.—The remaining solution consists now of *magnesia, potash, soda, and acetous acid*; to separate them let it be evaporated to dryness, and ignite it in a smooth crucible, until the acetous acid has been driven off by the heat; the remaining substance is to be extracted by warm water, as long as the water takes up any of it; the whole must then be transferred upon a filter, and the earth, which was the magnesia, be collected, dried, ignited, and its weight ascertained.

VIII.—The salt which the water had extracted from the residue, is again saturated with acetous acid, and if, after stirring the solution, any earthy precipitate is observed, it is to be filtered again, and the earth collected upon the filter: it is the portion of magnesia which had been taken up by the alcali, which is likewise to be dried and added to the weight of the magnesia obtained before.

IX.—The filtered liquid is again evaporated by a gentle heat to dryness and afterwards digested in alcohol. This will take up the potash combined with muriatic acid, and leave the soda behind; the alcoholic solution is evaporated to dryness, and re-dissolved in distilled water; and then mixed with acetite of lead, until all the muriatic acid is thereby separated; the precipitated muriate of lead is then separated by filtration, and the filtered liquid evaporated to dryness; afterwards ignited a little in a small smooth crucible, whose weight has been previously ascertained; when the acetous acid has been driven off by heat, the crucible is removed, and when cooled, it is immediately weighed: the overplus of the weight of the crucible indicates the weight of the potash. The muriate of soda, which was not dissolved, is likewise treated

in the same way, and thus the quantity of the soda ascertained.

If we now take each of the four separated ingredients, namely, the magnesia, soda, potash, and the iron, and saturate each separately with sulphuric acid, and then crystallise them; we become enabled by that means to ascertain the quantity of each of the salts in the state as they were contained in the earthy substance, pretty accurately.

This being a nice process, it requires great accuracy; and the rules for accomplishing it, would occupy more room than can be allotted them in this work.

PART V.

CLASS 4.

INFLAMMABLE FOSSILS.

The class of minerals remaining to be noticed, are those called inflammable or combustible fossils. They are divided in the following manner:

Genus I.—*Sulphur.*

Species 1.—Native Sulphur.

Varieties 1.—Coherent Native Sulphur.
2.—Earthy Native Sulphur.
3.—Volcanic Native Sulphur.

Genus II.—*Bitumen.*

Species 1.—Mineral or Fossil Oil.

Species 2.—Mineral Bitumen.

Varieties 1.—Elastic Mineral Bitumen.
2.—Earthy Mineral Bitumen.
3.—Slaggy Mineral Bitumen.

Species 3.—Brown Coal.

Varieties 1.—Bituminous Wood.
2.—Earthy Coal.
3.—Alum Earth.
4.—Common Brown Coal.
5.—Moor Coal.

Species 4.—Black or Pit Coal.

Varieties 1.—Pitch Coal.
2.—Columnar Coal.
3.—Slate Coal.
4.—Cannel Coal.
5.—Foliated Coal.
6.—Coarse Coal.

GENUS III.—*Graphite.*

Species 1.—Glance Coal.

Varieties 1.—Conchoidal.
2.—Slaty.

Species 2—Graphite.

Varieties 1.—Scaly.
2.—Compact.

Species 3.—Mineral Charcoal.

GENUS IV.—*Amber.*

Species 1.—Amber.

Varieties 1.—White.
2.—Yellow.
3.—Mellite, or honey stone

CHARACTERS OF INFLAMMABLE FOSSILS.

Inflammable fossils are such mineral substances as burn more or less easily, or whose principal character is inflammability at not very high temperatures. They are all insoluble, at least in their totallity in alcohol, as well as in water, and acids; but yield generally more or less to some species of volatile oil, or to sulphuric ether. Their specific gravity is below or scarcely exceed 2°, unless loaded with foreign matter.

NATURAL HISTORY OF COALS.

Coals are commonly found in hilly situations, always under strata of grit, which is a mixture of sand and clay; or under schistus, which is an indurated clay, splitting into layers, forming either slates, or a substance called shivers; according to its fracture. Coals are found on the mountains in strata, from a few inches to some feet in thickness, alternating with strata of grit stone and shistus. The beds of coals run in various directions, generally with a dip or inclination from the horizontal position. They are frequently intercepted by columns of other matter; and the continuation of the bed may be higher, or lower, than the part from which it has been, or seems to have been separated. The continuation too sometimes take the same, sometimes a very different degree of inclination, or dip. It generally happens that the first stratum of coals, that we come to, is not worth working, either from the inferior quality of the coal, or from the stratum being of too little depth. From the degree and direction of the dip, and the level of the country, much information is to be obtained, concerning the

proper places for opening the pit. A variety of circumstances require to be taken into consideration to work a coal mine to the greatest advantage, or to determine whether a mine ought to be worked at all. Even in countries or in those parts of the country, where none have been found, very probable conjectures may be formed concerning their presence, by attending to the soil, to the general appearance of the country, and to the kind of clay, sand, or other earth, that is found when the soil is removed. There are certain appearances that indicate the presence of coals; but these indications are subject to variations, and often appreciable by other rules. The business of mining in this department, is therefore intricate as that of ores, and none ought to enter upon it, without a practical knowledge of it, or the assistance of a practical miner.

With respect to the origin of coals, the most probable supposition is this:

That they originate from vegetables; but a few forests being buried in the earth are not sufficient to form the mountains of coal which exist in its bowels. A greater cause more proportioned to the magnitude of the effect is required; and we find it only in that prodi-

glous quantity of vegetables which grow in the sea, and is increased by the immense mass of those which are carried down by rivers. These vegetables carried away by the currents, are agitated, heaped together, and broken by the waves, and afterwards become covered with strata of argillaceous earth, or sand; they undergo a gradual decomposition, and form so many strata of coal, placed alternately with strata of clay and sand. It is indeed easier to conceive how these masses of vegetables may form strata of coal, than that remains of shells, should form so great a part of the globe.

That the coal itself is of vegetable origin, is fairly inferred from a variety of vegetables, remains, and impressions of animals, that are both found in the strata of coal, and in the earthy strata, above and below them. That it is of submarine origin, also appears obvious from the presence of shells, the impressions of fish, and other productions of the ocean. The popular opinion that coals grow like vegetables, so that the mines that are exhausted may be opened again and worked after a series of years, is too erroneous to need any formal refutation. We need not however be alarmed for the want

of future generations, as to this useful article. The immense beds of coal yet untouched will amply supply many thousands of generations to come; and there is no doubt but the same process that produced what we at present use, is still continued, and that some future convulsions of nature will bring to light new coal mountains perhaps from the bottom of the ocean; for that it is most probable is the place where nature had fixed her laboratory, for preparing this fuel for distant ages. For the modern practice of searching for coals the reader is referred to the author's System of Mineralogy, article *Coal.*

ANALYSIS OF INFLAMMABLE FOSSILS.

The complete analysis of inflammable fôssils would require a particular treatise: our object, however, is merely to determine in a ready manner the relative proportion of combustible matter, or carbon, which different species of coal are capable of yielding to be enabled to judge in some respect which are most advantageous in the ordinary processes of combustion: for the method of accomplishing this we are indebted to Kirwan. The only combustible substance of what it will be necessary to speak for that purpose, are coals.

Coals, at least those which are chiefly em-

ployed for fuel are composed of carbon or charcoal, bitumen, some portion of earth, and a small quantity of metallic matter.

The proportion of carbon may be ascertained by observing the quantity of nitrate of potash which a given quantity of coal is capable of decomposing. This may be effected in the following manner. Let 500 grains, or more of perfectly pure nitrate of potash be fused in a crucible, and when red hot, let the coal to be examined, coarsely powdered, be projected on the fused nitre, by little at a time, not exceeding one or two grains. Immediately when the detonation produced by the addition of one projection of coal has ceased, add a new portion till it produces no farther effect. The proportion of carbon in the coal is directly proportionate to the quantity required for the decomposition of the nitrate of potash. Thus Kirwan found that 12.709 of carbon are necessary to decompose 100 of nitrate of potash: it will be easy to deduce the quantity of carbon, in a given weight of coal, from the quantity of nitrate of potash which it is capable of decomposing. Kirwan found that 480 grains of nitrate of potash required 50 of Kilkenny coal to decompose it by

this method. Therefore 10 grains would have decomposed 96 of nitrate of potash; precisely the quantity of charcoal which would have produced the same effect. Therefore Kilkenny coal is composed almost entirely of carbon. Cannel coal, when burnt in this manner, left a residuum of 3.12 in the 100 parts of earthy ashes, 66.5 of it were required to decompose 480 grains of nitrate of potash, but 50 of charaoal would have been sufficient: therefore 66.5 grains of Cannel coal contain 50 grains of charcoal, and 2.08 of earth; the remaining 14.42 grains must be bitumen.

In a similar manner the composition of any other coal may be ascertained.

The proportion of earthy, or metallic ingredients may be ascertained by burning the coal, with free access of air. What remains unburnt must be considered as an impurity, its weight may be ascertained, and the nature of the earthy and metallic substances analysed, according to the rules laid down in the preceding pages.

PART VI.

ANALYSIS

OF

MINERAL WATERS.

THE compleat and accurate analysis of mineral waters is one of the most difficult subjects of chemical research, and requires a very extensive acquaintance with the properties and habitudes of a numerous class of substances. Such minuteness, however, is scarecely ever required in the experiments that are subservient to the ordinary purposes of life; a general knowledge of the composition of bodies being sufficient to assist in directing the most useful applications of

them. We shall not attempt, therefore, to lay down rules for the most accurate analysis, but shall only describe such as are suited to afford an insight into the kind, but not to decide the exact proportion of the constituent principles of natural waters.

Before proceeding, however, to the analysis of a water, it is proper to inquire into its natural history, and to examine attentively its physical characters. The temperature of the water must be carefully observed, and the quantity inquired into, which it yields in a given time. The sensible qualities of taste, smell, degree of transparency, &c. are also best ascertained at the fountain-head. The specific gravity of the water must be found according to the rules pointed out, page 29.

EXAMINATION OF MINERAL WATERS BY RE-AGENTS.

The readiest way of judging of the contents of mineral waters are by apylying tests or re-agents. The chief of which are the following:

Infusion of Litmus, is a test of most uncombined acids.

If the infusion redden the unboiled, but not

the boiled water, we may infer, that the acid is a volatile one, and most probably the carbonic acid. Sulphuretted hydrogen gas, dissolved in water, also reddens litmus, but not after boiling.

To ascertain whether the change be produced by carbonic acid or by sulphuretted hydrogen, when experiment show that the reddening cause is volatile, add barytic water. This, if carbonic acid be present, will occasion a precipitate, which will dissolve, with effervescence, on adding a little muriatic acid. Sulphuretted hydrogen may also be contained, along with carbonic acid, in the same water; which will be determined by the tests hereafter to be described. Paper tinged with litmus is also reddened by the presence of carbonic acid, but regains its blue colour on drying.

Infusion of Litmus reddened by Phosphoric Acid,—Tincture of Brazil-wood,—Tincture of Turmeric, and Paper stained with each of these three Substances,—Tincture of Red Cabbage.— All these different tests have one and the same object.

Infusion of litmus, reddened by phosphoric acid, or litmus paper reddened by it, has its blue colour restored by alcalies and earths, and by

carbonated alcalies and carbonated earths. Turmeric paper and tincture are changed to a reddish-brown by alcalies, whether freed from carbonic acid or not, by earths, freed from carbonic acid, but not by carbonated earths.

The red infusion of brazil-wood, and paper stained with it, become blue by alcalies and earths, and even by the latter, when dissolved by an excess of carbonic acid. In the last-mentioned case, however, the change will either cease to appear, or will be much less remarkable, when the water has been boiled.

Tincture of cabbage, is, by the same causes, turned green; as is also paper stained with the juice of the violet, or with the scrapings of radishes.

Tincture of Galls.—Tincture of galls is employed for discovering iron, with which it produces a black tinge. The iron, however, in order to be detected by this test, must be in the state of a red oxid, or, if oxidized in a less degree, its effects will not be apparent, unless after standing some time in contact with the air. By applying this test before and after evaporation, or boiling, we may know whether the iron be held in solution by carbonic acid, or by a fixed acid; for,

1. If it produce its effect before the application of heat, and not afterward, carbonic acid is the solvent.

2. If after, as well as before, a fixed and vulgarly called mineral acid is the solvent.

3. If, by the boiling, a yellowish powder be precipitated, and yet galls continue to strike the water black, the iron, as often happens, is dissolved both by carbonic acid and by a fixed acid.

Sulphuric Acid.—Sulphuric acid discovers, by a slight effervescence, the presence of carbonic acid, whether uncombined or united with alcalies or earths.

2. If lime be present the addition of sulphuric acid occasions, after a few days, a white precipitate.

3. Barytes is precipitated instantly, in the form of a white powder.

4. Nitric or muriatic salts, in a dry state, or dissolved in very little water, on adding sulphuric acid, and applying heat, are decomposed; and if a stopper, moistened with solution of ammonia, be held over the vessel, white clouds will appear. For distinguishing whether nitric or muriatic acid be the cause of this appearance, rules will be given hereafter.

Oxalic Acid and Oxalates.—This acid is a most delicate test of lime, which it separates from all its combinations.

1. If a water, which is precipitated by oxalic acid, become milky on adding a watery solution of carbonic acid, or by blowing air through it from the lungs, by means of a quill or glass tube, we may infer that lime (or barytes, which has never yet been found pure in waters) is present in an uncombined state.

2. If the oxalic acid occasion a precipitate before, but not after boiling, the lime is dissolved by an excess of carbonic acid.

3. If after boiling, by a fixed acid. A considerable excess of any of the mineral acids, however, prevents the oxalic acid from occasioning a precipitate, even though lime be present; because some acids decompose the oxalic, and others dissolving the oxalate of lime, prevent it from appearing. (Vide Kirwan on Waters, page 88.)

The oxalate of ammonia or of potash are not liable to the above objection, and are preferable, as re-agents, to the uncombined acid. Yet even these oxalates fail to detect lime when supersaturated with muriatic or nitric acids; and, if such an excess be present, it must be saturated, before

adding the test, with ammonia. A precipitate will then be produced.

The quantity of lime, contained in the precipitate, may be known, by first igniting it with access of air, which converts the oxalate into a carbonate; and by expelling, from this last, the carbonic acid, by a strong heat, in a covered crucible. According to Dr. Marcet, 117 grains of sulphate of lime give 100 of oxalate of lime, dried at 160° Fahrenheit.

Fluate of ammonia is also a most delicate test of lime.

Barytic Water.—1. Barytic Water is a very effectual test for detecting the presence of carbonic acid, with which it forms a precipitate which is soluble with effervescence in dilute nitric, or better in muriatic acid.

2. Barytic water is also a most sensible test of sulphuric acid and its combinations, which it indicates by a precipitate *not soluble* in muriatic acid.

Metals.—Of the metals, silver, bismuth, and mercury, are tests of the presence of hidro-sulphurets, and of sulphuretted hidrogen gas. If a little quicksilver be put into a bottle, containing water impregnated with either of these substances, its surface soon acquires a black film, and, on shaking the bottle, a blackish powder

separates from it. Silver leaf and bismuth are speedily tarnished by the same cause.

Sulphate, Nitrate, and Acetate of Silver.— These solutions are all, in some measure, applicable to the same purpose.

They are peculiarly adapted to the discovery of muriatic acid and of muriates, with which they form a white precipitate. A precipitation, however, may arise from other causes, which it may be proper to state. The solutions of silver in acids are precipitated by carbonated alcalies and earths. The agency of the alcalies and earths may be prevented, by previously saturating them with a few drops of the same acid in which the silver is dissolved. The nitrate and acetate of silver are decomposed by the sulphuric and sulphureous acids; but this may be prevented by adding, previously, a few drops of nitrate or acetite of barytes, and, after allowing the precipitate to subside, the clear liquor may be decanted, and the solution of silver added. Should a precipitate now take place, the presence of muriatic acid, or some of its combinations, may be suspected. To obviate uncertainty, whether a precipitate be owing to sulphuric or muriatic acid, a solution of sulphate of silver may be employed, which, when

no uncombined alcali or earth is present, is affected only by the latter acid.

The solutions of silver are also precipitated by sulphuretted hidrogen, and by hidro-sulphurets; but the precipitate is then reddish, or brown, or black; or it may be, at first, white, and afterwards become speedily brown or black. It is soluble, in great part, in dilute nitrous acid, which is not the case if occasioned by muriatic or sulphuric acid.

The solutions of silver are precipitated by extractive matter; but in this case, also, the precipitate has a dark colour, and is soluble in nitrous acid.

Acetate of lead.—Acetate of lead is a test of sulphuretted hidrogen and of hidro-sulphurets of alcalies, which occasion a black precipitate; and if a paper, on which characters are traced with a solution of acetate of lead, be held over a portion of water containing sulphuretted hidrogen gas, they are soon rendered visible, especially when the water is a little warmed.

Muriate, Nitrate, and Acetate of Barytes.—These solutions are all most delicate tests of sulphuric acid and of its combinations, with which they give a white precipitate, insoluble in dilute

muriatic acid. They are decomposed, however, by carbonated alcalies; but the precipitates occasioned by carbonates is soluble in dilute muriatic or nitric acid, with effervescence, and may even be prevented by adding previously a few drops of the same acid as that contained in the barytic salt, which is employed.

One hundred grains of dry sulphate of barytes contain (according to Klaproth, vol. I. p. 168.) about $45\frac{1}{2}$ of sulphuric acid of the specific gravity 1850; according to Clayfield, (Nicholson's Journal, 4to, iii. 38.) 33 of acid, of specific gravity 2240; according to Thenard, after calcination, about 25; and according to Mr. Kirwan, after ignition, 23.5 of real acid. The same chemist states, that 170 grains of ignited sulphate of barytes denote 100 of dried sulphate of soda; while 136.36 of the same substance indicate 100 of dry sulphate of potash; and 100 parts result from the precipitation of 52.11 of sulphate of magnesia.

From Klaproth's experiments, it appears that 1000 grains of sulphate of barytes indicate 595 of desiccated sulphate of soda, or 1416 of the crystallised salt. The same chemist has shown that 100 grains of sulphate of barytes are pro-

duced by the precipitation of 71 grains of sulphate of lime.

Prussiates of Potash and of Lime.—Of these two, the prussiate of potash is the most eligible. When pure, it does not speedily assume a blue colour, on the addition of an acid, nor does it *immediately* precipitate muriate of barytes.

Prussiate of potash is a very sensible test of iron, with the solutions of which in acids it produces a Prussian blue precipitate, in consequence of a double elective affinity. To render its effect more certain, however, it may be proper to add, previously, to any water suspected to contain iron, a little muriatic acid, with a view to the saturation of uncombined alcalies or earths, which, if present, prevent the detection of very minute quantities of iron.

1. If a water, after boiling and filtration, does not afford a blue precipitate, on the addition of prussiate of potash, the solvent of the iron may be inferred to be a volatile one, and probably the carbonic acid.

2. Should the precipitation ensue in the boiled water, the solvent is a fixed acid, the nature of which must be ascertained by other tests.

In using the prussiate of potash for the discovery of iron, considerable caution is necessary,

in order to attain accurate results. The prussiate should, on all occasions, be previously crystallised; and the quantity of oxid of iron essential to its constitution, or at least an invariable accompaniment, should be previously ascertained in the following manner: Expose a known weight of the crystallised salt to a low red heat in a silver crucible. After fusing and boiling up, it will become dry, and will then blacken. Let it cool; wash off the soluble part; collect the rest on a filter; dry it, and again calcine it with a little wax. Let it be again weighed, and the result will shew the proportion of oxid of iron present in the salt which has been examined. This varies from 22 to 30 and upwards per cent. When the test is employed for discovering iron, let a known weight of the salt be dissolved in a given quantity of water; add the solution gradually; and observe how much is expended in effecting the precipition. Before collecting the precipitate, warm the liquid, which generally throws down a further portion of Prussian blue. Let the whole be washed and dried, and then ignited with wax. From the weight of the oxid obtained, deduct that quantity, which, by the former experiment, is known to be present in the prus-

siate that has been added; and the remainder will denote the quantity of oxid of iron present in the liquor which is under examination.

Succinate of Soda and Succinate of Ammonia are also tests for iron.

In applying these agents it is necessary not to use more than is sufficient for the purpose; because an excess of them re-dissolves the precipitate. The best mode of proceeding is to heat the solution containing iron, and to add gradually the solution of succinate, until it ceases to produce any effect. A brownish precipitate is obtained, consisting of succinate of iron. This, when heated with a little wax, in a low red heat, gives an oxid of iron containing about 70 per cent. of the metal.

The succinates, however, precipitate alumine, provided there be no considerable excess of acid in the aluminous salt. On magnesia they have no action, and hence they may be successfully employed in the separation of these two earths.

Phosphate of Soda.—An easy and valuable method of precipitating magnesia has been suggested by Dr. Wollaston. It is founded on the property which fully neutralized carbonate of ammonia possesses; first to dissolve the carbonate of magnesia formed, when it is added to

the solution of magnesian salt. For this purpose a solution of carbonate of ammonia, prepared with a portion of that salt which has been exposed, spread on a paper, for a few hours, to the air, is to be added to the solution of the magnesian salt sufficiently concentrated; or to a water suspected to contain magnesia, after being very much reduced by evaporation. No precipitate will appear, till a solution of phosphate of soda is added, when an abundant one will fall down. Let this be dried in a temperature not exceeding 100° Fahrenheit. One hundred grains of it will indicate 19 of magnesia, or about 64 of muriate of magnesia.

Muriate of Lime.—Muriate of lime is principally of use in discovering the presence of alcaline carbonates, which, though they very rarely occur, have sometimes been found in mineral waters. Of all the three alcaline carbonates, muriate of lime is a sufficient re-agent; for those salts separate from it a carbonate of lime, soluble with effervescence in muriatic acid.

With respect to the discrimination of the different alcalies, potash may be detected by muriate of platina, see page 517. Carbonate of ammonia may be discovered by its smell; and by its precipitating a neutral salt of alumine,

while it has no action apparently on magnesian salts.

To estimate the proportion of an alcaline carbonate present in any water, saturate its base with sulphuric acid, and note the weight of real acid which is required. Now 100 grains of real sulphuric acid saturate 121.48 potash, and 78.32 soda.

Analysis of Waters by Evaporation.—The reader, who may wish for rules for the complete and accurate analysis of mineral waters, will find in almost every chemical work a chapter allotted to this subject. He may consult Kirwan's Essay on the Analysis of Mineral Waters, London, 1799. As this manual, however, may sometimes be employed as a travelling companion, and may attend the mineralogist where other works cannot be had, it may be proper to state, briefly, the mode of analysing waters by the more certain, but still not unobjectionable, mode of evaporation.

Before evaporation, however, the gaseous products of the water must be collected, which may be done by filling with it a large glass bottle, or retort, capable of holding about 50 cubic inches, and furnished with a ground stopper and bent tube. The bottle is to be placed up to its neck,

in a kettle filled with brine, which must be kept boiling for an hour or two, renewing, by fresh portions of hot water, what is lost by evaporation. The disengaged gas is conveyed, by a bent tube, into a graduated jar, filled with, and inverted in, mercury, where its bulk is to be determined. On the first impression of the heat, however, the water will be expanded, and portions will continue to escape into the graduated jar till the water has obtained its maximum of temperature. This must be suffered to escape, and its quantity to be deducted from that of the water submitted to experiment.

In determining, with precision the quantity of gas, it is neccessary to attend to the state of the barometer and thermometer.

The gases most commonly found in mineral waters, are *carbonic acid*; *sulphuretted hidrogen*; *nitrogen*; *oxigen gas*; and, in the neighbourhood of volcanoes only, *sulphureous acid gas*.

To determine the proportion of the gases, constituting any mixture obtained from a mineral water in the foregoing manner, the following experiments may be made. If the use of reagents has not detected the presence of sulphuretted hidrogen, and there is reason to believe, from the same evidence, that carbonic acid

forms a part of the mixture, let a graduated tube be nearly filled with it over quicksilver; pass up a small portion of solution of potash, and agitate this in contact with the gas; the amount of the diminution will show how much carbonic acid has been absorbed; and, if the quantity submitted to experiment was an aliquot part of the whole gas obtained, it is easy to infer the total quantity present in the water. The unabsorbable residuum consists, most probably, of oxigen and azotic gases; and the proportion of these two is best learned by the use of Dr. Hope's eudiometer.

If sulphuretted hidrogen be present, along with carbonic acid, the separation of these two is a problem of some difficulty. Mr. Kirwan recommends that a graduated glass vessel, completely filled with the mixture, be removed into a vessel containing nitrous acid. This instantly condenses the sulphuretted hidrogen, but not the carbonic acid gas. I apprehend, however, that a more eligible mode will be found to be, the condensation of the sulphuretted hidrogen by oxi-muriatic acid gas (obtained from muriatic and hyper oxi-muriate of potash), adding the latter gas very cautiously, as long as it produces any condensation. Or, perhaps, a better plan

of effecting the separation is the following, recommended by Mr. Henry: half fill a graduated vial with the mixed carbonic acid and sulphuretted hidrogen gases, and expel the rest of the water by oxi-muriatic acid gas. Let the mouth of the bottle be then closed with a well ground stopper, and let the mixture be kept twenty-four hours. Then withdraw the stopper under water, a quantity of which fluid will immediately rush in. Allow the bottle to stand half an hour without agitation. The redundant oxi-muriatic acid gas will thus be absorbed; and very little of the carbonic acid will disappear. Supposing that, to 10 cubic inches of the mixed gases, 10 inches of oxi-muriatic gas have been added, and that, after absorption, by standing over water, 5 inches remain, the result of this experiment shews, that the mixture consisted of equal parts of sulphuretted hidrogen and carbonic acid gases.

Whenever this complicated admixture of gases occurs, as in the Harrowgate and in some of the Cheltenham waters; it is advisable to operate separately on two portions of gas, with the view to determine, by the one, the quantity of carbonic acid and sulphuretted hydrogen; and that of azote and oxigen by the other. In the latter

instance, remove both the absorbable gases by caustic potash, and examine the remainder in the manner already directed.

Nitrogen gas sometimes occurs in mineral waters, almost in an unmixed state. When this happens, the gas will be known by the characters already described as belonging to it. Sulphureous acid gas may be detected by its peculiar smell of burning sulphur, and by its discharging the colour of an infusion of roses, which has been reddened by the smallest quantity of any acid adequate to the effect.

(*a*) The water should next be evaporated to dryness. The dry mass, when collected and accurately weighed, is to be put in a bottle, and highly rectified alcohol poured on it, to the depth of an inch. After having stood a few hours, and been occasionally shaken, pour the whole on a filter, wash it with a little more alcohol, and dry and weigh the remainder.

(*b*) To the undissolved residue, add nine times its weight of cold distilled water; shake the mixture frequently; and, after some time, filter; ascertaining the loss of weight.

(*c*) Boil the residuum, for a quarter of an hour, in sometimes more than 500 times its weight of water, and afterwards filter.

(*d*) The residue, which must be dried and weighed, is no longer soluble in water or alcohol. If it has a brown colour, denoting the presence of iron, let it be moistened with water, and exposed to the sun's rays for some weeks.

I.—The solution in alcohol (*a*) may contain one or all of the following salts: muriates of lime, magnesia, or barytes, or nitrates of the same earths. Sometimes, also, the alcohol may take up sulphate of iron, in which the metal is highly oxidized, as will appear by its reddish-brown colour.

1. In order to discover the quality and quantity of the ingredients, evaporate to dryness; weigh the residuum; add above half its weight of strong sulphuric acid; and apply a moderate heat. The muriatic or nitric acid will be expelled, and will be known by the colour of their fumes; the former being white, and the latter orange coloured.

2. To ascertain whether lime or magnesia be the basis of the salts, let the heat be continued till no more fumes arise, and let it then be raised to expel the excess of sulphuric acid. To the dry mass, add twice its weight of distilled water. This will take up the sulphate of magnesia, and leave the sulphate of lime. The two sulphates

may be separately decomposed, by boiling with three or four times their weight of carbonate of potash. The carbonates of lime and magnesia, thus obtained, may be separately dissolved in muriatic acid, and evaporated. The weight of the dry salts will inform us how much of each the alcohol had taken up. Lime and magnesia may also be separated by the use of phoshate of soda, as stated in page 545.

II.—The watery solution (*b*) may contain a variety of salts, the accurate separation of which from each other is a problem of considerable difficulty.

1. The analysis of this solution may be attempted by crystallisation. For this purpose let one half be evaporated by a very gentle heat, not exceeding 80° or 90°. Should any crystals appear on the surface of the solution, while hot, in the form of a pellicle, let them be separated and dried on bibulous paper. These are muriate of soda, or common salt. The remaining solution, on cooling very gradually, will perhaps, afford crystals distinguishable by their form and other qualities. When various salts however are contained in the same solution, it is extremely difficult to obtain them sufficiently distinct to ascertain their kind.

2. The nature of the saline contents must therefore be examined by tests, or re-agents.

The presence of an uncombined alcali, as well as uncombined acids, will be discovered by the stained papers, and tests already pointed out. The vegetable alcali or potash, may be distinguished from the mineral, or soda, by muriate of platina, see page 517.

If neutral salts be present in the solution, we have to ascertain both the nature of the acid and that of the base. This may be done by attention to the rules already given for the application of tests, which it is unnecessary to repeat in this place.

III.—The solution by boiling water contains scarcely any thing besides sulphate of lime.

IV.—The residuum (*d*) is to be digested in distilled vinegar, which takes up magnesia and lime, but leaves, undissolved, alumine and highly oxidized iron. Evaporate the solution to dryness. If it contain acetate of lime only, a substance will be obtained which does not attract moisture from the air; if magnesia be present, the mass will deliquesce. To separate the lime from the magnesia, proceed as in I.

The residue insoluble in acetous acid, may contain alumine, iron, and silex. The two first

may be dissolved by muriatic acid, from which the iron may be precipitated first by prussiate of potash, and the alumine afterward by a fixed alcali.

For a more circumstantial detail the reader is referred to Kirwan's excellent Essay on the Analysis of Mineral Waters; and for illustrative examples of several practical analyses to the Author's Analysis of the Mineral Waters of Cheltenham, and its neighbourhood.

THE END.

DESCRIPTION

OF

THE PLATES

PLATE I.

Fig. I. represents a hydrostatic balance, of which a description has been given already, pages 19, 20, 21.

Fig. 2, represents a perspective view of a portable universal furnace. It is made of hammered sheet iron, and lined with fire bricks 3 inches thick. The height of the body of the furnace is 18 inches, its inner diameter measures 8 inches. In the front of the furnace are 3 openings, *a a a*, perpendicularly over each other, furnished with doors. In either of the two upper openings a muffle may be placed, for performing the operations of assaying, or for roasting and desulphurating ores, to prepare them for the subsequent operations of reduction or smelting. The lower door closes the ash-pit, and serves to regulate the heat at pleasure, by opening or shutting it more or less, accordingly. B is the cover of the furnace. It consists of a thick iron plate, lined with fire clay. In the center of this cover is a hole through which the operation carried on in the furnace, or the state of the fire may be inspected without scorching the face. C is a stopper made of crucible ware, which fits the hole in the cover B. D. is the elbow of the chimney, which may be elongated by an additional tube, and then directed into the fire place of the apartment. If a very intense heat be required, the tube or chimney of the furnace should be at least 5 or 6 ft. high. If the fire

be well attended to, the intensity of the heat will be sufficient for the reduction of the ores of iron, copper, nickel, cobalt, or any other processes which require the most violent heat. A great variety of operations in the small way may be carried on in this useful furnace, which béing heavy and substantial, is very durable and not liable to be damaged by accidental blows, or easily displaced. It is besides extremely convenient, and perfectly safe in a room. The thickness of the walls of the chimney prevent the operator from being at all molested by the intensity of the heat. Coke and charcoal are the best fuel for this furnace, but common coal answers also very well.

Fig. 3, is an improved lamp-furnace. It consists of a brass rod screwed into a solid foot of the same metal. On this rod slides a circular lamp, *a a*, constructed on Argand's plan, which may, by means of a spring, be elevated or depressed at pleasure: *b b* are circular rings for supporting flasks, basons, retorts, &c. They may be set nearer to, or farther from the flame of the lamp by means of the socket and thumb screws, F F.

Fig. 4 represents Davy's apparatus for the analysis of soils.—See page 505.

Fig. 5, a blow-pipe spoon, which should be made of platina.—See page 36.

Fig. 6, an apparatus for easily ascertaining the quantity of carbonic acid disengaged from any substance by the action of an acid: it consists of a bottle closed by a cork or stopper, into which is fixed a spiral tube terminating into a capillary opening. To use this apparatus, ascertain first what quantity of muriatic or nitric acid is required to saturate a given quantity of the substance, intended to be submitted to the experiment. Having done this, put the quantity of acid or rather more into the bottle, and weigh the whole accurately; then add to it the substance, the quantity of carbonic acid gas of which is to be ascertained, cork the bottle as expeditiously as possible, and suffer the carbonic acid to escape. When the effervescence has completely ceased, let the whole apparatus be again weighed, and the loss of weight will indicate the quantity of carbonic acid contained in the substance, with tolerable acccuracy.

The spiral tube prevents the carbonic acid from carrying off moisture.

Fig. 7, a chemical thermometer so constructed that the lower part of the scale board may be turned up by means of a hinge, which renders the instrument very useful for taking the temperature of small quantities of fluids, or of mixtures in which acids form a part. The chemical thermometer should be graduated from 40° below 0 up to 600° Fahrenheit. The figures expressing the value of the graduations are omitted in the drawing.

Fig. 8, a bottle for readily ascertaining specific gravities of fluid. It consists of a vial with a slender neck, and ground stopper, having a mark made with a diamond in the neck of it. When this bottle is filled up to the mark with distilled water of a given temperature it should hold exactly 1000, 2000, or any even number of grains. The quantity which it is found to contain of any other fluid at the same temperature denotes the specific gravity of the latter fluid. For example, if it holds 1000 grains of water, and 1850 of sulphuric acid, the specific gravity of the sulphuric acid is to that of water as 1850 to 1000.

PLATE II.

Fig. 1. a portable forge. An instrument of great utility, chiefly for the reduction of ores in the *dry way*, for by means of it the most intense heat may quickly be produced, and conveniently applied to any substance whatever. *a*. a blowpipe which may occasionally be attached to the double bellows.

Fig. 2, an apparatus for drying the products of analysis. The substance to be dried must be placed in the conical glass vessel *b*, and when the vessel *c* is filled with water up to the side tube *d*, the desiccation may be performed by putting the apparatus over a lamp, and keeping the water in a state of ebullition. It is particularly useful in drying the precipitates obtained in analyses; for it is well known that the same mineral, analysed by different chemists, has been found to yield different proportions of the same ingredients, and that the different

weights of the constituent parts, in many cases, are often more apparent than real; arising entirely from the various degrees of desiccation that has been employed by different analysts, and sometimes even by the same person. This point is of such importance, and is productive of so much trouble, that every chemist who has analysed a mineral water, or crystallised, or separated small quantities of deliquescent salts, will at once perceive the utility of the apparatus in this respect.

Fig. 3, and 4, Crucible stands.

Fig. 5, an improved blowpipe. It consists of a conical tube furnished with a small pipe near the base, to which jets, or caps of different perforations may be adapted. The air is forced into the blow-pipe by the mouth of the operator, or by means of a bladder or double bellows attached to the instrument. The substance to be fused must be placed upon a piece of charcoal, or held in a small spoon made of platina, or wrapped up in a piece of platina foil. The quantity of the substance to be examined by means of the blow-pipe ought not to exceed the size of a pepper corn.

Fig. 6, an ingot, spoken of page 38.

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